A REVIEW OF THE BIOLOGICAL CONTROL OF INSECTS AND WEEDS IN AUSTRALIA AND AUSTRALIAN NEW GUINEA

by

FRANK WILSON

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Division of Entomology, C.S.I.R.O., Canberra, Australia

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FOREWORD

It has long been felt that there should be available a general summary of biological control investigations and introductions which have been made in and on behalf of the different countries of the Commonwealth. In fact, in the Commonwealth Agricultural Bureaux Review Conference 1950 it was recommended that a Commonwealth-wide survey should be made of the results obtained in this field.

A large proportion of the biological control investigation in the Commonwealth has been carried out by the Commonwealth Institute of Biological Control, but there has also been a considerable number of additional investigations made by the individual countries concerned, and a number of introductions of beneficial species has also been made into different areas against a variety of pests on the initiative of individual entomologists or Departments of Agriculture in various parts of the Commonwealth.

This review of biological control in Australia is a comprehensive work in which all introductions made in attempts at biological control into Australia and Australian New Guinea have been listed, and the results obtained assessed as far as possible. This latter is difficult, and Mr. Wilson is to be congratulated on the objective manner in which this has been done, and also on the efforts he has made to obtain details of all the early introductions of beneficial species which have been made into this area.

It is hoped that similar reviews for other parts of the Commonwealth will follow in due course, since they would be very valuable to economic entomologists in general, and to biological control workers in particular.

F. J. SIMMONDS,
Director,
Commonwealth Institute of Biological Control

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INTRODUCTION

Australian interest in biological control was initially aroused by American entomologists who visited Australia in search of parasites and predators of Californian and Hawaiian pests. Some of the natural enemies obtained in Australia were the means of great successes in insect control. Albert Koebele, who came to Australia in 1888 and 1891 on behalf of the United States Department of Agriculture, sent to California many valuable insects, including *Rodolia cardinalis*, *Cryptochaetum iceryae*, *Rhizobius ventralis* and *Cryptolaemus montrouzieri*, and his highly successful investigations led to Australia being visited by many other workers in the field of biological control—George Compere, R. C. L. Perkins, F. Muir, Harold Compere, C. E. Pemberton, E. J. Vosler, S. E. Flanders and others.

American achievements, and the fact that many of Australia's agricultural and horticultural pests were exotic species, gave rise to the hope that biological control would solve some of the country's principal insect problems. Western Australia displayed particular interest in this possibility, and in 1895 its Bureau of Agriculture published a proposal to initiate a system of exchange of useful insects with other colonies or foreign countries. This led to the exchange between Western Australia and the States of eastern Australia, during several years, of various coccinellids. The first insect to be established was apparently *Leis conformis*, which was introduced into Western Australia in 1896.

In 1901, Western Australia appointed George Compere as Entomologist to the Department of Agriculture, with the duty of introducing into the State natural enemies of its principal insect pests. Compere continued his work until 1910 (though from 1904 onwards he worked jointly for Western Australia and California), and during these years he travelled widely about the world and introduced many parasites and predators into Australia. Many of these species were not identified, and much of this early work is poorly documented.

The biological control of weeds was advocated in Australia as early as 1899, when it was suggested that insects should be introduced for the control of prickly pear in Queensland. The first use of an insect for weed control in Australia was the distribution of a native species, *Antonina australis*, in eastern Australia for the control of nut-grass. The use of this insect began in 1901, if not earlier. In 1903, Henry Tryon attempted unsuccessfully to introduce *Dactylopius indicus* for the control of prickly pear, but more than twenty years passed before the biological control of prickly pear gave those remarkable results which are now so widely known. While the impetus for this work derived in part from Hawaiian attempts to control lantana, it also arose from the fact that the ability of *Dactylopius indicus* to destroy *Opuntia vulgaris* had been observed in India and Ceylon, following the introduction of that insect into India in 1795 for the development of a dye industry.

During a period that now extends over about sixty years, the introduction of natural enemies of insects and weeds has continued steadily, but slowly by comparison with the number of pests requiring control and the large number of natural enemies that could be introduced. This relatively slow rate of importation results from the uncertainty that biological control will provide a solution for any given problem, the time-consuming nature of the work, the large empirical element in such investigations, and the limited financial provision made for biological control in a period in which chemical control has predominated. It is becoming increasingly evident, however, that chemical means tend to magnify the problems they cope with, and to create fresh problems in the process. The increasing complexity of spray schedules, their mounting expense, and the associated outbreaks of once innocuous species, point to the desirability of basing the control of pests so far as possible upon natural controls, and of employing chemical controls in such a manner that they supplement rather than replace natural controls. It is therefore a suitable time to review Australian work on biological control and to clarify the contribution that it has made to Australian agriculture.

Virtually all work on the biological control of pests in Australia has been undertaken by Commonwealth and State authorities, of which the following are the more important:

Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.)—formerly Council for Scientific and Industrial Research (C.S.I.R.)
Commonwealth Department of Territories. Papua-New Guinea Department of Agriculture, Stock and Fisheries
Commonwealth Prickly Pear Board (ceased 1939)
New South Wales Department of Agriculture
Queensland Department of Agriculture and Stock
Queensland Department of Public Lands
Queensland Bureau of Sugar Experiment Stations
South Australian Department of Agriculture
Tasmanian Department of Agriculture
Victorian Department of Agriculture
Victorian Department of Lands and Survey
Waite Agricultural Research Institute
Western Australian Department of Agriculture

Biological control investigations are almost invariably of an international character and depend to an exceptional degree upon collaboration between entomological institutions in different parts of the world. The institutions to which Australia is indebted are too numerous to list, but the Commonwealth Institute of Biological Control, the Commonwealth Institute of Entomology and various institutions in California, Hawaii and other parts of the United States have been of particular help to Australian workers.

The authority to grant permission for the introduction and liberation of natural enemies of pests in Australia is vested in the Commonwealth Department of Health.

The present paper is concerned to examine all attempts at the biological control of insects and weeds in Australia and Australian New Guinea, and to provide a substantially complete list of sources for each problem. So far as the sources permit, reference is made to all natural enemies which have been deliberately introduced. In addition to discussing attempts at the biological control of pests, reference is often made to their native and accidentally introduced natural enemies in Australia, without attempting to make the lists of such natural enemies exhaustive or necessarily providing the sources for the information given. Australian New Guinea comprises the Australian Territories of Papua and New Guinea, and includes the eastern half of the mainland of New Guinea, the Bismarck Archipelago, and Bougainville Island in the Solomon Islands. This review does not cover biological control research in Dutch New Guinea and the British Solomon Islands.

*Sources**
7, 61, 115, 158, 317, 511, 517.

*The source numbers given refer to the numbers of the papers as listed in the bibliography. When a source number refers to the annual reports of an institution, the relevant years are given in brackets.

BIOLOGICAL CONTROL OF INSECTS

GENERAL

A number of papers of a general or review character have been published. W. W. Froggatt, who was critical of the biological control method, expressed his views in two papers published in 1902 and 1909 (207, 214). Johnston (328) discussed the general subject of the biological control of pests in a report issued in 1928. Veitch (525) dealt briefly in 1932 with biological control in Queensland, Miller (378) summarized in 1947 the results of attempts at the biological control of insect pests in Tasmania, and Jenkins (317) in 1946 provided a review of Western Australian work. Evans (172) gave some information on biological control in his review of injurious insects in the British Commonwealth. Dun (153) included a good deal of information on biological control in Papua and New Guinea in a paper published in 1955. Wilson (555) has reviewed the results of biological control investigations in Australia and New Guinea.

Among papers bearing on the biological control of insects are the contributions to the dynamics of animal populations by A. J. Nicholson. These papers (427–30, 432, 434–40), which examine the various influences that affect population densities and the population densities these lead to, include much that is fundamental to biological control investigations. The practical implications of Nicholson's views were discussed in a paper (429) published in 1940.

Sources
153, 172, 207, 214, 317, 328, 378, 427, 428, 429, 430, 432, 434, 435, 436, 437, 438, 439, 440, 525, 555.

CONTROL OF SPECIFIC INSECT PESTS

The pests which have been the subject of biological control in Australia and New Guinea have been predominantly those which are troublesome on orchard trees and garden and field crops. Silvicultural pests have required little attention because there are relatively few important exotic pests in Australian forests or in commercial stands of timber.

The various attempts at the biological control of insect pests are reviewed below and references to the work on two snails and a tick are included. These pests can be separated into the following categories, (A) Orchard and Fruit pests; (B) Garden and Field pests; (C) Silvicultural pests and (D) Miscellaneous pests.

A. ORCHARD AND FRUIT PESTS

(1) **Coconut grasshoppers**—*Sexava nubila* St. and *S. novae-guineae* Branc., (Tettigoniidae, Orth.)

Sexava nubila and *S. novae-guineae* are the most important of some six tettigoniid species which cause severe defoliation and loss of yield to coconuts in the Bismarck Archipelago. Attempts have been made to control these insects by parasite introductions. Important egg-parasites of *Sexava* occur in New Hanover and Amboina, but no parasites of apparent importance were found in Manus District or New Ireland.

Leefmansia bicolor Water.(Encyrtidae) was bred from *Sexava coriacea* L. in Amboina, and ineffective efforts were made to introduce it into the Territory of New Guinea in 1929–33. It was established in Manus District in 1933, New Hanover in 1934, and New Britain in 1935. It bred freely in the eggs of *S. nubila* and *S. novae-guineae*. In 1948, *L. bicolor* was introduced from New Hanover into Keravat, New Britain, and became established, parasitizing up to 70 per cent. of the host-eggs. On several occasions since the war, outbreaks of *Sexava* have been brought under control in parts of New Britain and New Ireland by mass liberations of this parasite. Before the war, it was found that *L. bicolor* was not well able to maintain itself in the field although it bred very easily in

captivity. Since the war, it has maintained itself well in the field at Keravat, New Britain, and on several occasions outbreaks of *Sexava* have been brought under control by mass liberation of this wasp in New Britain and New Ireland. Stocks are usually kept on hand to deal with sudden outbreaks.

Another egg-parasite, *Doirania leefmansi* Water.(Trichogrammatidae), was introduced in 1933 from Amboina into Manus District, but no adults were obtained. This parasite was subsequently found in New Hanover, and was liberated in New Britain in 1935, and in Manus District in 1935–6. It was also introduced into Keravat, from New Hanover in 1948, but failed to become established. *D. leefmansi* is reported to control *Sexava* spp. in New Hanover.

Two other egg-parasites of *Sexava* have been introduced into Manus Island from New Hanover, an encyrtid species in 1935–7, and a mymarid in 1937. The encyrtid was introduced from New Hanover into New Britain in 1935.

Colonies of eggs, possibly parasitized by three or more parasites, were transferred from Manus and New Hanover to New Ireland and New Britain Districts in 1937–8.

On the mainland of New Guinea, the plantations are free from economic damage by *Sexava*, and here the adults and nymphs are parasitized by a strepsipteron and a tachinid, both of which it is hoped to transfer to the areas where *Sexava* is a pest. The strepsipteron, *Stichotrema dallatoreanum* Hof.(Stichotrematidae) will attack *Sexava nubila*, but work with this parasite has been hampered as the females appear to require fertilization, and males are unknown. Attempts to establish it in New Britain have so far been unsuccessful although several isolated recoveries were made at Keravat.

Sources

150, 151, 152, 153, 191, 192, 194, 195, 198, 395, 396, 400, 448, 502 (1935–6, 1937–8, 1955–7), 503 (1955–6).

(2) **Woolly aphid**—*Eriosoma lanigerum* (Hausm.) (Aphididae, Hem.)

The woolly aphid was for many years an extremely important pest of apple trees in all Australian States. The use of resistant stocks was pioneered in Victoria in 1868–70, using Winter Majetin, but of the many resistant varieties discovered, Northern Spy was the most effective and came into general use. Resistant stocks proved highly successful in preventing the development of subterranean colonies of woolly aphid, and the use of such stocks quickly spread to other countries. The problem presented by aphid infestation of the aerial part of the tree remained, however, as severe as before.

Predators of woolly aphid in Australia include the coccinellids, *Leis conformis* Boisd., *Coccinella repanda* Thunb., *C. repanda* ab. *transversalis* F., *Chilomenes quadriplagiata* Swartz and *Rhizobius* sp., the syrphids, *Syrphus viridiceps* Macq. and *S. pusillus* Frogg., and chrysopids. The most important of these is possibly *Leis conformis*, which was introduced into Western Australia from New South Wales and Tasmania in 1896–1902 (see (4) "Aphids and scale insects") primarily for the control of woolly aphid. It became established there and proved of some use in the control of this aphid.

The New South Wales Department of Agriculture in 1900 introduced *Exochomus melanocephalus* (Zoubk.) from South Africa to control woolly aphid, but the predator was not established.

In 1911, the Victorian Department of Agriculture introduced a coccinellid from Western Australia for the control of woolly aphid and red scale. This coccinellid, which did not become established, may have been *Chilomenes quadriplagiata*, which was at one time distributed in Western Australia for the control of these two pests.

Aphelinus mali (Hald.) (Eulophidae) was introduced into Australia in 1923. Before this introduction, a parasite considered by Girault to be *Aphelinus mali* (*niger* Gir.) was obtained in Queensland and New South Wales, having been reared from 'chrysanthemum aphis' and collected as adults in an apple orchard. It appears, however, that before the introduction of material from New Zealand, woolly aphid in Australia was not attacked by this parasite.

New Zealand imported three 'strains' of *Aphelinus mali* from Connecticut, Arkansas, and Georgia, U.S.A. Apparently, the Georgia strain did not survive and the material imported into Australia was derived from the other two. The introductions of *Aphelinus mali* into the different States were as follows:

Introduced			Initial liberation
Into	From	Year	
Western Australia	New Zealand	1923	1923
Queensland	New Zealand	1923	1923
Tasmania	Western Australia	1923	1923
	Western Australia	1924	1924
New South Wales	New Zealand	1924	1925
Victoria	New Zealand and Western Australia	1924	1925
South Australia	New Zealand	1923–4	(not liberated)
	Western Australia	1924	1924–5
	New Zealand and Western Australia	1925	(not liberated)
	Queensland and Victoria	1926	1926
Australian Capital Territory	New South Wales	1936	1936

In all the States, releases of *Aphelinus mali* were made for several seasons, and the parasite was established readily everywhere except for some initial difficulties in South Australia.

In Western Australia, the parasite proved within four years to be highly effective, and its control of woolly aphid is regarded as one of the State's outstanding achievements in biological control. Although infestations develop on the new wood in the earlier part of the season, insecticidal control is seldom necessary.

In Queensland, *Aphelinus mali* is highly efficient during the months in which host increase is normally at its peak, and it has permitted the reduction of spray applications from six or seven annually to at most two, one in spring and one in autumn.

In Tasmania, the parasite has reduced woolly aphid to the status of a minor pest. In some seasons, especially in the cooler areas, the activities of the parasite lag behind those of the host, and insecticidal control may then be needed. The practice of raising apple trees on resistant stocks is no longer followed, and the majority of apple trees are now growing on seedling stocks.

In all the fruit-growing districts of Victoria, *Aphelinus mali* gives a high degree of control. In some seasons, however, some trees become heavily infested, and such infestations require chemical control.

Similarly in New South Wales, *A. mali* controlled woolly aphid so effectively that spraying became generally unnecessary, although the aphid often becomes relatively abundant in early spring. Reduction in parasite numbers in the spring may be caused by winter and spring spraying against woolly aphid or by pruning the aphid-infested wood in winter, and it is recommended that the aphid-infested prunings be stored and placed outdoors in the orchard at blossoming time or a little later.

In South Australia, *A. mali* has provided substantial control of the host, though in some seasons the aphid appears to increase before the parasites become active and it is necessary to spray some trees. In the colder districts, the aphids are controlled by *A. mali*, but in warmer districts the aphid populations sometimes develop substantially before the parasite becomes active in the spring.

As *Aphelinus mali* is unable to gain access to woolly aphid below ground, the combination of subterranean control by resistant stocks and aerial control by parasites is felicitous. Except in Tasmania, resistant apple root-stocks are still in predominant use in Australia, most trees still being planted on the Northern Spy stock.

The high level of control of *E. lanigerum* generally given by *A. mali* in Australia has been emphasized by the marked tendency of DDT, when applied to apple trees to control codling moth, to cause heavy infestations of woolly aphid by destroying *A. mali*. This has been reported widely by growers and entomologists in virtually all States. To counter this adverse effect, it has been suggested that infested twigs bearing parasitized aphids should be collected in autumn and returned to the orchards in spring, and that some trees in each orchard be left unsprayed.

Sources

43, 46, 47, 53, 75, 127, 133, 137, 160, 163, 170, 179, 184, 206, 244, 247, 269, 275, 303, 304, 305, 306, 307, 308, 309, 310, 317, 320, 337, 338, 342, 347, 352, 353, 363, 378, 402 (1900, 1924–8, 1945–6, 1949–52), 403 (1946–50, 1951–2), 410, 414, 415, 416, 417, 421, 425 ,441, 462, 469 (1925–33), 470, 492 (1922–35), 501 (1923–5, 1930–4, 1947–8), 505, 523, 527, 528, 537, 542 (1910–1, 1912–4, 1915–6, 1923–8, 1947–9), 545, 558.

(3) **Black citrus aphid**—*Toxoptera aurantii* (Boy.) (Aphididae, Hem.)

An 'orange aphis', referred to as *Siphonophora citrifolii* Ashm., was troublesome in Western Australia before 1900. Presumably, the species concerned was *Toxoptera aurantii*. Its natural enemies in that State included *Chilomenes quadriplagiata*, *Coccinella repanda* ab. *transversalis*, two syrphid species, and an ichneumonid parasite. The comparative rarity of this aphid in eastern Australia was attributed to the predator *Leis conformis*, and this coccinellid was introduced into Western Australia from New South Wales and Tasmania in 1896–1902 (see (4) "Aphids and scale insects") and was established.

Unspecified parasites of 'black orange aphis' were introduced into Western Australia from Marseilles, France, in 1903. Jenkins (317) mentions other unspecified parasites of 'black aphis' being introduced into this State from Algeria in 1906, and from Ceylon in 1907 and 1909.

Aphelinus mali, introduced into Australia for the control of woolly aphid in 1923, has been recorded to parasitize black citrus aphid in Western Australia and Queensland. The type of *Aphobetoideus comperei* Ashm.(Pteromalidae) was reared from *Toxoptera aurantii* in Western Australia. Natural enemies of *Toxoptera aurantii* recorded in New South Wales are the coccinellids *Leis conformis*, *Coccinella repanda*, *C. repanda* ab. *transversalis*, *Callineda testudinaria* (Muls.), *Coelophora veranioides* Blackb., and *Scymnus lividigaster* (Muls.): other predators of 'citrus aphids' in this State are *Chrysopa* sp. (Chrysopidae) and *Xanthogramma grandicorne* (Macq.) (Syrphidae).

Sources
16, 133, 137, 173, 309, 317, 347, 403 (1946–8, 1949–50), 410, 416, 451, 541 (1896–7), 542 (1910–2).

(4) Aphids and scale insects

Many general predators of aphids and scale insects, chiefly coccinellids, have been introduced into several Australian States. During the period 1895–1902, there were many exchanges of coccinellids between Western and eastern Australia; after that period, most introduced species came from overseas. The recorded introductions are listed below as accurately as possible. The list includes some but not all of the coccinellids mentioned under other headings. As many of the species introduced have not been identified, and others were not identified initially, some introductions may be listed more than once. However, where the introduction of an unidentified species seemed to correspond with the recorded introduction of a named species, the former is not listed. In addition to coccinellid predators of aphids and scale insects, the list includes coccinellid predators of red mites and mealy bugs, several syrphid and noctuid predators, and some parasites of aphids.

The coccinellids, *Coccinella repanda* ab. *transversalis*, *Rhizobius ventralis* (Er.), and *Rodolia cardinalis* (Muls.), were all recorded to be present in the south of Western Australia before their introduction was undertaken: also, *Leis conformis* (Boisd.) ab. *occidentalis* Lea was already present there before the introduction of *Leis conformis*. *Rodolia cardinalis*, before its introduction into Western Australia in 1902, had already been reported, together with other natural enemies, to keep *Icerya purchasi* Mask.(Monophlebidae) entirely in check in that State.

Useful coccinellids established in Western Australia are *Orcus chalybeus* (Boisd.) and *Leis conformis*, as well as *Cryptolaemus montrouzieri* (Muls.), which is not included in this list. However, few of the species introduced are known to have become established, though living material of most of them was released. The failure to establish more of these coccinellids probably resulted from the small numbers liberated, the weakened condition of specimens liberated after long journeys by slow transport, inadequate knowledge of the insects' hosts and other requirements, the change in season arising from movement to the southern hemisphere, and unsuitable climate.

Sources
8, 11, 12, 13, 15, 16, 28, 62, 63, 98, 99, 104, 132, 135, 136, 137, 180, 206, 234, 317, 345, 347, 402 (1900), 405, 406, 407, 412, 530 (1907–10), 542 (1897–8, 1907–8).

(5) **Black scale**—*Saissetia oleae* (Bern.) (Coccidae, Hem.)

Saissetia oleae occurs in all the States of Australia. It is not now a major pest anywhere, but is somewhat more important in South Australia, Victoria and New South Wales. Formerly, it was of

Natural enemies of aphids and coccids introduced into Australia

Natural enemy	Introduced			Hosts	Establishment
	By	From	Year		
Predators					
COCCINELLIDAE					
Scymnus (*Platyomus*) *lividigaster* (Muls.)	Western Australia	Eastern Australia	1902	Aphids	Not established
Rhizobius ventralis	Western Australia	New South Wales	1898	Black scale, etc.	
	Western Australia	Eastern Australia	1902		
	Tasmania	New South Wales	1902		
Rhizobius sp.	Western Australia	Eastern Australia	1902	Black scale, etc.	
Rhizobius sp.	Western Australia	Ceylon	1909		
Rodolia koebelei (Oll.)	Western Australia	New South Wales	1902		
Rodolia cardinalis	Western Australia	New South Wales	1902	Fluted scale	
	Melbourne, Vic.	?	?–1902		Not established
Chilocorus circumdatus (Schönh.)	Western Australia	Hong Kong	1902	*Aspidiotus*	Not established
Chilocorus stigma Say (*bivulnerus* Muls.)	Western Australia	California	1907	Aphids, scale insects	
	New South Wales	California	1927	San José scale	Not established
Orcus chalybeus	Western Australia	New South Wales	1902	Scale insects, etc.	Established
	Tasmania	New South Wales	1900		
Orcus bilunulatus (Boisd.)	Western Australia	Tasmania	1901	Scale insects	
Orcus lafertei Muls.	Western Australia	New South Wales	1902	Scale insects, aphids	Not established
Orcus sp.	Victoria	Queensland	*c.* 1907–10	Red scale	
Leis conformis	Western Australia	New South Wales	1896	Aphids, scale insects	Not established
	Western Australia	Tasmania	1897–8		
	Western Australia	New South Wales	1897–8		
	Western Australia	Tasmania	1901–2		Established
Leis sp.	New South Wales	California	1927	Scale insects	Not established
Oenopia sp.	New South Wales	California	1927	Scale insects	Not established
Olla abdominalis Say	New South Wales	California	1927	Scale insects	Not established
Chilomenes quadriplagiata Swartz (*quadripustulatus* Muls., *Orcus mollipes* Oll.)	South Australia	Western Australia	*c.* 1897	Aphids, scale insects	
	Tasmania	Western Australia	*c.* 1897		
	Tasmania	Western Australia	1902		
Verania lineola (F.)	Western Australia	New South Wales	1902	Aphids	Not established
Hippodamia convergens (Guér.)	Western Australia	California	1906, 1907	Aphids	Not established
Hippodamia convergens ab. *ambigua* J. Lec.	New South Wales	California	1927	Scale insects	Not established
Coccinella repanda Thunb.	Western Australia	New South Wales	1902	Aphids	
Coccinella repanda ab. *transversalis*	Western Australia	New South Wales	1897–8	Aphids	
	Western Australia	Victoria	1897–8		

[*continued overleaf*

Natural enemy	Introduced			Hosts	Establishment
	By	From	Year		
Coccinella septempunctata (L.)	Western Australia	Mediterranean	1903	Aphids	Not established
Coccinella transversoguttata Fald. ab. *californica* Mannh.	Western Australia	California	1906	Aphids	Not established
	New South Wales	California	1927	Aphids	Not established
Psyllobora vigintimaculata (Say) (*taedata* J. Lec.)	New South Wales	California	1927	Scale insects	Not established
Cleobora (*Halyzia*) *mellyi* Muls.	Western Australia	Tasmania	1901	Scale insects	
Coccinellid spp.	Victoria	Western Australia	*c.* 1898	Scale insects, etc.	
Coccinellid sp.	Western Australia	Seville, Spain	1903	*Aspidiotus*	
Coccinellid sp.	Western Australia	Malaga, Spain	1903	*Dactylopius*	
Coccinellid sp.	Western Australia	Marseilles, France	1903	Black orange aphid	
Coccinellid sp.	Western Australia	Marseilles, France	1903	Red mite	
Coccinellid sp.	Western Australia	Marseilles, France	1903		
Coccinellid spp. (2)	Western Australia	Hong Kong	1903	Aphids	Not liberated
Coccinellid sp.	Western Australia	Jerusalem	1904	Red scale	
Coccinellid spp. (several)	Western Australia	Marseilles, France	1904		
Coccinellid spp. (several)	Western Australia	China	1905	Aphids	
Coccinellid sp.	Western Australia	Italy	1906	Aphids	
Coccinellid sp.	Western Australia	India	1906	Aphids	
Coccinellid sp.	Western Australia	Japan	1907	Red scale	Not established
Coccinellid sp.	Western Australia	Ceylon	1907	Red scale	Not established
Coccinellid sp.	Western Australia	Spain	1907	Red scale	Not established
Coccinellid spp. (2)	Western Australia	Algiers	1907	Aphids	
Coccinellid sp.	Western Australia	California	1907	Scale insects	
Coccinellid spp. (5)	Western Australia	Colombo	1907	Aphids	
Coccinellid spp. (5)	Western Australia	India	1907	Aphids	
Coccinellid spp.	Western Australia	Germany	1908	Aphids	
Coccinellid sp.	Victoria	Western Australia	1911	Red scale, woolly aphid	Not established
SYRPHIDAE					
Syrphid spp. (2)	Western Australia	Malaga, Spain	1903	Aphids	
Syrphid spp.	Western Australia	Colombo	1907	Aphids	
Syrphid sp.	Western Australia	Philippines	1909	Aphids	
NOCTUIDAE					
Thalpochares spp. (2)	Western Australia	India	1908		
Parasites					
Parasite sp.	Western Australia	Queensland	1902	Aphid	
Parasite sp.	Western Australia	New South Wales	1902	Aphid	
Parasite spp. (2)	Western Australia	Seville	1903	Aphids	
Parasite sp.	Western Australia	Algiers	1906	Aphid	

greater significance. In Western Australia, it was once one of the most destructive orchard pests, but introduced parasites reduced its importance and it is now generally of little consequence in that State. In New South Wales also, black scale was once very plentiful in the County of Cumberland, but it has ceased to be a serious orchard pest through the control exercised by native and introduced insects. The various natural enemies probably have a similarly beneficial effect in the other States, though it has been suggested that pronounced fluctuations of black scale in South Australia may be attributable to weather fluctuations.

In 1895–8, Lea recorded that black scale had many natural enemies in Western Australia. These included two hymenopterous parasites, and the predators *Orcus australasiae* (Boisd.), *Orcus* sp., *Chilomenes quadriplagiata*, *Scymnus* sp., *Rhizobius ventralis*, *Thalpochares* sp., and two acarids. Subsequently, the following introductions of enemies of black scale were made by the Department of Agriculture of Western Australia:

	Introduced		
Natural enemies	Origin	Year	Establishment
Rhizobius ventralis	New South Wales	1898	
	Queensland and New South Wales	1902	See text
Rhizobius sp.	Queensland and New South Wales	1902	
Scutellista cyanea (Motsch. (Pteromalidae)	Capetown	1902	Not established
	Ceylon	*c.* 1903	Not established
	Brazil	1904	Not established
	California	1904	Established
Aphycus (*Metaphycus*) *lounsburyi* How.(Encyrtidae)	Capetown	1902	Established
Microterys sp. (Encyrtidae)	Capetown	1902	Not established
Tomocera californica How.(Pteromalidae)	New South Wales	1902	Established
Quaylea whittieri (Gir.) (Encyrtidae)	New South Wales	1902	Not established
Myiocnema comperei Ashm.(Eulophidae)	Queensland	1902	Established
Parasites (3)	Canton	1903	Not established
Unnamed species	Eastern Australia	1903	?
Unnamed species	South Africa	1903	?
Unnamed species	Brazil	1904	?
Unnamed species	California	1904	?
Scutellista sp.	China	1905	Not established
Scutellista sp. ('red scutellista')	Timor	1905	Not established

According to the literature, *Rhizobius ventralis* was established in Western Australia on its introduction in 1902 and Lea had pointed out that this predator was widely distributed there before he introduced it in 1898.

C. P. Clausen (unpublished parasite index) records that the following parasites were introduced into Australia: *Baeoanusia minor* (Silv.) (Encyrtidae) from South Africa in 1903, and *Lecaniobius utilis* Comp.(Eupelmidae) from Brazil in 1904. These records doubtless identify the two corresponding unnamed introductions in the above list.

According to Hooper (274), the material imported from South Africa, which included *Microterys* sp. and *Scutellista cyanea*, also included *Tetrasticlius* sp. (doubtless a misprint for *Tetrastichus* sp. (Eulophidae), but as this was recognized as a secondary parasite presumably it was not liberated.

Compere (98) records that among the black scale parasites introduced into Western Australia from eastern Australia in 1902 were two unnamed species as well as the three named in the list. Bailey (63) states that three of these parasites from eastern Australia were established.

The three parasites imported from Canton in 1903 were obtained from black scale on *Aristolochia* growing beside the Canton river. These parasites have been erroneously referred to in the literature as '*Aristolochia* sp.'

Despeissis (136) stated that, besides a number of coccinellid predators, 14 parasites were introduced into Western Australia against black scale and that 11 of these had become established. Whether this is true or not, the establishment of *Scutellista cyanea*, *Aphycus lounsburyi* and *Tomocera californica*

provided a level of control which is regarded as one of the outstanding successes of biological control in the State. Predators are also of some importance, especially *Orcus australasiae* and *Rhizobius ventralis*.

Aphobetoideus comperei was described from material collected at Perth, Western Australia in 1900–3. This parasite, *Quaylea whittieri*, *Myiocnema comperei*, and *Baeoanusia minor* are all secondary parasites of black scale (467). *Quaylea whittieri*, after its introduction into California, became the most important hyperparasite of *Tomocera californica*, *Scutellista cyanea*, and *Aphycus lounsburyi* (158).

Tomocera californica, although originally described (1880) from black scale in California, is probably of Australian origin.

In South Australia, in the Adelaide district, small outbreaks of black scale occur intermittently. In this State, the recorded natural enemies of black scale include *Rhizobius ventralis*, *Aphycus lounsburyi* (the most common parasite), *Coccophagus scutellaris* (Dalm.) (*lunulatus* How.) (Eulophidae), and *Microterys flavus* (How.) among others. *Scutellista cyanea*, which is so valuable in other parts of Australia, is apparently absent from South Australia. *Quaylea whittieri* occurs as a hyperparasite on *Aphycus lounsburyi*, and *Myiocnema comperei* is secondary or tertiary. *Coccophagus scutellaris* is scarce on *S. oleae*, apparently because of inability, in the absence of an alternative host, to bridge the gap in the sequence of generations.

In New South Wales, the parasites recorded include *Scutellista cyanea*, *Tomocera californica*, *Aphycus lounsburyi*, *Myiocnema comperei*, *Aphobetoideus comperei*, *Coccophagus scutellaris*, and *Aneristus ceroplastae* How. (*Coccophagus orientalis* How., *Prococcophagus orientalis* Timb.) (Eulophidae). *Catoblemma dubia* (Butl.) (*Eublemma cocciphaga* (Meyr.), *Thalpochares cocciphaga* Meyr.) (Noctuidae), *Rhizobius ventralis*, *Orcus chalybeus*, and *Orcus australasiae* have been recorded as predators, the first being one of the most important natural enemies of black scale in New South Wales.

In Queensland, *Aphycus lounsburyi* appears to be the parasite mainly responsible for the fact that black scale is seldom a pest of importance on any host, but *Scutellista cyanea* and *Catoblemma dubia* are also important. *Diversinervus elegans* Silv.(*Cheiloneuroides bicristatus* Gir., Encyrtidae) has been bred from black scale in this State. It is a primary parasite, though earlier thought to be a hyperparasite.

In 1942, C.S.I.R. introduced from California *Aphycus* (*Metaphycus*) *helvolus* Comp. This parasite was cultured during 1942–4, and consignments were sent to Western Australia in 1943 (no liberations made), and to New South Wales, Queensland and South Australia in 1943–4. The Waite Agricultural Research Institute maintained a colony of this parasite for some years, and made liberations in South Australia during 1943–7. *A. helvolus* was recovered in South Australia at most liberation areas around Adelaide and in the citrus areas of the Murray Valley, but its effect on the host has not been estimated. This parasite has also been reared in South Australia from *Coccus hesperidum* L. and other scales.

In general in Australia, natural enemies contribute substantially to the restriction of black scale to the status of a comparatively unimportant pest. Parasite and predator introductions have contributed greatly to this result, at least in Western Australia. However, as early as 1892, Koebele had reported on the prevalence of parasites of black scale in eastern Australia and this was corroborated later by G. Compere.

Sources

6, 15, 63, 75, 80, 88, 98, 99, 102, 104, 105, 116 (1942–6), 133, 135, 136, 137, 158, 175, 200, 224, 225, 274, 317, 344, 347, 403 (1948–9, 1953–5), 404, 407, 408, 410, 411, 417, 421, 467, 484, 485, 486, 497, 532, 533 (1943–7), 542 (1897–8, 1909–14, 1919–20, 1923–4, 1936–7, 1943–5).

(6) **Soft brown scale**—*Coccus hesperidum* L. (Coccidae, Hem.)

Coccus hesperidum occurs in all the States of Australia on a wide range of fruit trees and other plants. It is nowhere a major pest, although it has some importance in South Australia, Western Australia and New South Wales.

In 1895 Lea (344) noted the presence in Western Australia of a predator, *Orcus australasiae* and two parasites of soft brown scale. Later, the Department of Agriculture introduced the following enemies of the scale into this State:

Parasites	Introduced		Establishment
	Origin	Year	
Parasite spp. (2)	Queensland and New South Wales	1902	
Parasite spp. (2)	China	1905	
Parasite spp.	China	1906	Not liberated
Parasite spp.	Algiers	1906	Not liberated
Parasite spp.	China	1906	
Parasite sp.	California	1907	
Parasite spp.	Ceylon	1907	
Parasite spp.	India	1907	
Coccophagus lycimnia (Walk.) (*lecanii* (Fitch))	California	1907	
Scutellista sp.	Philippine Islands	1907	Not established
Scutellista sp.	Colombo	1907	Not established
Scutellista sp.	Ceylon	1908	
Parasite species (1)	Italy	1908	
Parasite species (1)	Egypt	1908	
Scutellista sp. and others (see text)	China and India	1909	

Slides in the Western Australian Department of Agriculture of parasites of *C. hesperidum* have been examined by E. F. Riek. These slides, which are mostly more than twenty-five years old, include the following parasites:

(1) A species of *Cristatithorax* (Encyrtidae) imported from China (presumably in 1905 or 1906). Evidently this species was established for it was reared from *Eulecanium persicae* in 1950.

(2) A second species of *Cristatithorax* introduced from Queensland (presumably in 1902).

(3) A parasite, named on the slide as *Microterys flavus* How., introduced from California (presumably in 1907).

(4) A species of *Coccophagus* imported from India (presumably in 1907 or 1909) and named on the slide as *C. orientalis* How.

(5) Another species of *Coccophagus*, named on the slide as *C. scutellaris*.

(6) Two species of *Myiocnema*, named on the slides as *M. comperei* and *M. flavithorax* Gir.

(7) A species of *Aphycus* named on the slide as *A. verdini* Gir.

(8) A mymarid species, named on the slide as *Erythmelus schilleri* Gir.

(9) An encyrtid species, bred in Perth, named on the slide as *Eucomys hortensis* Gir.

Parasites of *Coccus hesperidum* were collected and distributed in Western Australia for many years until about 1925. Bailey (63) in 1904 referred to the establishment of a parasite of this scale (presumably a species imported in 1902 from eastern Australia) and commented that it nearly cleaned up trees that had been almost covered with soft brown scale two years earlier. Newman (407) stated in 1907 that three parasites of the scale, including *Coccophagus lycimnia*, had been established, and that all three also parasitized the vine scale (*Eulecanium persicae*). In the period 1908–10, Newman referred to the presence in Western Australia of four internal parasites of soft brown scale, and commented that, although once very serious, soft brown scale had diminished in importance and was only troublesome where the parasites were not established. *Coccophagus lycimnia* was reported to have been distributed in Western Australia as late as 1920–1. However, Jenkins (317) does not list any of the parasites introduced against soft brown scale as definitely established, and concludes that the attempt at the biological control of this scale was not successful.

Rhizobius ventralis may be a predator of some importance on *Coccus hesperidum* in Western Australia, as it is in eastern Australia. Other parasites recorded from soft brown scale in Western Australia are *Coccophagus scutellaris* and *Aphytis proclia* (Walk.) (*Aphelinus fuscipennis* How.) (Eulophidae).

In Queensland, *C. hesperidum* is rare, and any colonies are rapidly destroyed by natural enemies, which include *Rhizobius ventralis*, *Catoblemma* sp., *Aphycus flavus* How., *Aphycus verdini* Gir., *Aphelinus* sp. and *Eucomys* sp. Artificial control is never required.

Numerous natural enemies have been recorded in South Australia, where soft brown scale is widely distributed. These include *Aphycus alberti* How., *Coccophagus scutellaris*, *Aphycus lounsburyi*, *Microterys flavus*, *Myiocnema comperei*, *Aphycus helvolus* (introduced against *Saissetia oleae*), *Rhizobius ventralis* and others. *Coccophagus scutellaris* also occurs on *Saissetia oleae*, but is more abundant on *Coccus hesperidum*. *Myiocnema comperei* is reported to be a secondary or tertiary parasite. In this State, at present at least, soft brown scale is regarded as a serious problem on Murray Valley citrus plantings. This is particularly so where insecticides are used for other purposes. DDT has been used in South Australia in citrus groves and produces massive infestations by *C. hesperidum*, which support huge ant populations (D. C. Swan, personal communication.)

In New South Wales, *Cryptolaemus montrouzieri*, *Rhizobius ventralis*, *Catoblemma dubia*, *Catoblemma* sp., *Aphycus alberti* and other parasites are known to attack this scale.

There is little doubt that, in Australia, *C. hesperidum* is generally kept substantially under control by natural enemies, but the relative importance of the numerous natural enemies (whether native or alien species) is largely unknown.

Sources

6, 22, 23, 28, 63, 75, 98, 104, 133, 135, 136, 137, 317, 344, 347, 403 (1948–50, 1954–5), 404, 405, 407, 408, 410, 411, 485, 486, 497, 510, 533 (1943–7), 542 (1907–8, 1909–14, 1920–1).

(7) **Red scale**—*Aonidiella aurantii* (Mask.) (Diaspididae, Hem.)

Red scale is generally regarded as the most important pest of citrus in Australia, although its importance differs in different areas. In Queensland, it is reported to show a marked preference for hot, dry conditions. In South Australia, it is a serious pest in the irrigated areas of the lower Murray Valley, but in the upper Murray Valley it is confined to restricted areas by drastic control measures.

Between 1895 and 1897, the natural enemies of red scale observed in Western Australia included unspecified hymenopterous parasites, *Rhizobius debilis* Blackb. and an acarid. Lea noted that *Orcus chalybeus* was a useful red scale predator in the eastern part of Australia, and suggested that, as this coccinellid was not present in the southern part of Western Australia, it should be introduced.

The Department of Agriculture of Western Australia introduced the following insect enemies of red scale during the period 1902–9:

	Introduced		
Predator or parasite	Origin	Year	Establishment
Orcus chalybeus	New South Wales	1902	Established
Parasite sp.	Southern China	1902	
Parasite spp.	Hong Kong	1903	Not established
Coccinellid sp.	Seville, Spain	1903	
Coccinellid sp.	Jerusalem	1904	(See text)
Aphytis chrysomphali (Merc.)	China	1905	Established
Parasite sp.	Japan	1907	
Parasite spp. (2)	Colombo	1907	
Parasite sp.	China	1907	
Parasite spp. (7)	India	1907	
Parasite spp. (2)	?	1908	Not established
Parasite spp. (6 or more)	Far East	1909	

The preceding list has been drawn up from the original sources and is as accurate as the sources permit.

The parasites introduced in 1903 and 1908 did not emerge from the imported material and were not liberated. The parasites introduced in 1902 and 1905, and those introduced from Japan, China, and Colombo in 1907, were all liberated. The seven species from India (1907) are recorded as being bred in Western Australia, and the six or more species from the Far East (1909) are recorded as emerging and ovipositing in red scale, and a few at least were released. It is quite possible that many of these Indian and Far Eastern parasites were liberated.

The coccinellid introduced from Jerusalem in 1904 was also released. It was reported for a few years after its liberation to be abundant and to attack red scale effectively, but may have disappeared subsequently. The name of this species is unknown.

The parasite listed above under the name *Aphytis chrysomphali* was introduced by G. Compere from China in November 1905, and established from the fourteen or fifteen specimens obtained. This insect was referred to in the early Australian literature as *Aphelinus diaspidis* and *Aphelinus fuscipennis*. Since that time, the name *chrysomphali* has come into use for the common parasite of red scale and yellow scale, *Aonidiella citrina* (Coq.), in Australia. However, the species of *Aphytis* parasitizing red scale and yellow scale in Australia need taxonomic investigation. H. Compere considers that circumstantial evidence indicates that the species George Compere collected in southern China in 1906 (*sic*) and attempted to introduce into California and Western Australia was probably *Aphytis lingnanensis* Comp. (*Aphytis* 'A') and not *chrysomphali*. These species were confused until after 1947. Further, the common parasite of red scale, to which the name *chrysomphali* (Merc.) is applied, may or may not be Mercet's species, and has been confused with *diaspidis* (How.) and *citrinus* Comp. It is uncertain whether *diaspidis* ever reproduces on red scale, but *citrinus*, so far as is known, only attacks yellow scale (108).

The parasite introduced from China, which it is convenient to call *Aphytis chrysomphali*, is widely established in Western Australia and is considered, in some coastal districts at least, to help keep red scale populations within reasonable limits.

Of the seven species introduced from India in 1907, one is reported to have been a species of *Aphelinus*. According to reports made in 1907, a second parasite of red scale became established in Western Australia, but the species was not identified.

Other natural enemies of red scale in Western Australia include the predators, *Batrachedra* sp. (Cosmopterygidae), *Rhizobius debilis*, *Orcus australasiae* and *Chilomenes quadriplagiata*. The last two were distributed at one time in Western Australia for the control of red scale.

Aphytis chrysomphali was sent from Western Australia to New South Wales in 1925–6. This parasite and others are reported to attack red scale and yellow scale in New South Wales, causing very heavy mortality, especially to yellow scale in coastal areas. These natural enemies are most effective on trees which are free from heavy dust deposits. Where sprays such as strong Bordeaux mixture are applied, the heavy residues have an adverse effect. Residual sprays, such as DDT, by killing the natural enemies of the scales, induce a rapid increase in infestation. In this State, both red and yellow scales are attacked by *Orcus chalybeus*, the most important coastal predator, and *Lindorus lophanthae* (Blaisd.) (Coccinellidae), which is more common inland. *Aspidiotiphagus australiensis*, *Catoblemma dubia*, *Batrachedra* sp., *Orcus australasiae*, *Leis conformis* and chrysopids are also recorded as enemies of red scale in New South Wales. In general in this State, natural enemies are of some limited value in reducing scale populations.

Casca chinensis How.(Eulophidae) has been reared from circular black scale, *Chrysomphalus ficus* Ashm., collected in Sydney, N.S.W. This parasite has also been reared from Chinese material of *Chrysomphalus* sp., which was first considered to be red scale and then doubtfully regarded as yellow scale. *C. chinensis* was originally described in 1907 from specimens reared from Chinese material of the purple scale, *Lepidosaphes beckii* (Newman), and more than one species of *Casca* may be involved. Flanders (176) lists *Casca chinensis* and *Casca wannsiensis* Comp. as Chinese parasites of red scale, and *Casca* n. sp. as a parasite of yellow scale in China and Formosa.

Aphytis chrysomphali is considered a most useful species in Queensland, where, in the late summer months, natural enemies sometimes quickly bring severe infestations under control; *Aphytis chrysomphali* also attacks *Chrysomphalus ficus*, and white louse scale, *Unaspis citri* (Comst.), in this State. Other parasites and predators of red scale in Queensland are *Rhopalencyrtoidea dubia* Gir. (Encyrtidae), *Coccophagus iris* Gir., *Tomocera californica*, *Orcus chalybeus* and *Catoblemma dubia*.

In South Australia, *Aphytis chrysomphali* is usually present only in small numbers and is patchy in distribution. The most important natural enemy of red scale in this State is *Lindorus lophanthae*; others include chrysopids and *Anystis baccarum* (Linn.) (Anystidae).

The Victorian Department of Agriculture introduced *Orcus* sp. from Queensland about 1907–10 for the control of red scale, and a coccinellid predator of both red scale and woolly aphid from Western Australia about 1911. The second (possibly *Chilomenes quadriplagiata*) was not established.

In 1942, C.S.I.R. imported from California material of the Chinese race of *Comperiella bifasciata* How.(Encyrtidae). This was cultured and liberated in all the mainland States in 1943–4. The Waite Agricultural Research Institute, maintained a culture for several years, and made liberations in South Australia until 1947, sending consignments to Western Australia in 1947–9. Further importations of this race of *C. bifasciata* were made by C.S.I.R.O. in 1947–9, and further liberations were made in that period in Queensland, Victoria and New South Wales. Recoveries of this parasite were made in New South Wales, Western Australia, South Australia and Victoria, but it is known to be established only in the last two. Its effect on red scale abundance is unknown.

There is a recent suggestion from Merbein, Victoria, that natural enemies (principally native lacewings) are able to control red scale satisfactorily. A low level of red scale infestation occurs on a property which has not received regular scale-control treatments for about eleven years. In consequence, it has been suggested that citrus growers, while continuing their customary spray and fumigation schedules, should leave an area untreated to foster the natural enemies of this pest. The Victorian Department of Agriculture is also concerned to encourage the spread of *Comperiella bifasciata*, and intends to introduce the red scale strain of *Prospaltella perniciosi* Tower(Eulophidae) (58).

Though no adequate study has yet been made of the effect of natural enemies on the abundance of red scale in Australia, it is evident that the existing parasites and predators are of marked value. Nevertheless, red scale remains a major problem, and insecticides play an important part in its control.

Sources

6, 7, 11, 15, 20, 21, 22, 23, 29, 55, 58, 62, 63, 68, 80, 88, 97 (1948–54), 99, 104, 106, 108, 116 (1942–8), 133, 136, 137, 158, 176, 267, 316, 317, 347, 353, 371, 402 (1925–6), 403 (1947–50, 1953–5), 404, 405, 406, 407, 408, 410, 411, 412, 417, 451, 469 (1942–3), 483, 497, 530 (1907–10), 533 (1941–7), 542 (1907–8, 1909–29, 1943–9).

(8) **Vine scale**—*Eulecanium persicae* (F.) (Coccidae, Hem.)

Vine scale is now only a minor pest in Australia, and of no importance at all outside Western Australia and Victoria. In the early years of this century, it was a serious pest of grape vine, plum and other plants in Western Australia, where it was first observed in 1901. The Department of Agriculture introduced the following natural enemies for the control of this and closely related species:

	Introduced		
Parasites	Origin	Year	Establishment
Ichneumonid sp. (1) and chalcid sp. (1)	Southern France	1903	Not established
Aphycus timberlakei Ishii	? California	? 1907	Established
Coccophagus lycimnia	California	1907	(see text)
Parasite spp. (2)	California	1907	
Parasite spp. (3)	Philippines	1909	

There is reason for doubt as to the source of the material and date of introduction of *Aphycus timberlakei*. Jenkins (317) lists the species as being introduced from California in 1907. Although this parasite was apparently not introduced into U.S.A., Compere was in Japan in 1906 and returned *via* California to Western Australia, arriving in March 1907. He may have made the introduction at this time.

In 1907, Newman (407) reported that during the year three parasites of *Coccus hesperidum* which also attacked the vine scale (one being *Coccophagus lycimnia*) had been established. However, in 1908 he reported (410) that the vine scale was gradually spreading, and that the parasites introduced against it were actually parasites of soft brown scale which they were attacking. Two years later, the Department of Agriculture reported that during the summer all the *Lecanium* scales (vine scale at that time was called *Lecanium cymbiforme* Sign.) were heavily parasitized. This suggests that *Aphycus*

timberlakei might have been one of the three parasites introduced from the Philippines in 1909, and indeed O'Connor (447) has dated this introduction at "about 1910". The identity of this species was not known until Girault identified specimens in 1932. The species was described from Japanese material in 1923.

Of the parasites introduced, *A. timberlakei* became widely established in Western Australia and has since controlled vine scale with great efficiency. It was reported in 1924–5 that '*Coccophagus*' had proved useful against vine scale in Western Australia, but it is not known whether this refers to *Coccophagus lycimnia.*

A species of *Cristatithorax* imported from China for the control of soft brown scale has been reared from vine scale in Western Australia. The specimen occurs on a slide in the Departmental collection in Perth. *Muscideopsis lecanii* Gir.(Pteromalidae) has also been bred from vine scale in Western Australia.

It was apparently *A. timberlakei* which was introduced (as *Scutellista cyanea*) into Victoria from Western Australia about 1923, and is reported to have very effectively controlled vine scale in Victoria in about two years. A second liberation of *A. timberlakei* was made in the same area about 1933.

Aphycus timberlakei was sent from Western Australia to New South Wales in 1926–7. In this State, the vine scale is common in vineyards but seldom causes any serious injury, and is usually confined to a few vines. It is normally kept in subjection by many natural enemies which include several wasp parasites, and the predators *Cryptolaemus montrouzieri* and *Catoblemma dubia.* Should the natural balance be upset, as for example by spraying with DDT, a rapid and spectacular increase in infestation may occur (268).

In South Australia, where vine scale is of widespread occurrence on vine and other plants in Adelaide, the female scales are usually heavily parasitized by unspecified species.

Sources
16, 23, 80, 99, 133, 136, 137, 158, 238, 268, 317, 353, 406, 407, 410, 412, 447, 542 (1907–8, 1909–14, 1924–9).

(9) **White wax scale**—*Ceroplastes destructor* Newst. (Coccidae, Hem.)

Ceroplastes destructor is an important citrus pest in Western Australia, New South Wales and Queensland. It is considered to be an introduced species of African origin.

The biological control of this scale was undertaken by the New South Wales Department of Agriculture. Field work was carried out in Kenya and Uganda, and incidentally in India, where the Indian white wax scale, *Ceroplastes ceriferus* (And.), which also occurs in Australia, is indigenous. Consignments of parasites or parasitized *Ceroplastes* were imported into Australia from Kenya (1935–8), Uganda (1935), and India (1936).

The host material collected in Kenya and Uganda was of uncertain species of white wax scales collected chiefly from coffee but also from fruit trees. From this African material, twenty-five parasite species, chiefly encyrtids, were obtained, ten or twelve being thought to be primary parasites. These included the following species:

Scutellista cyanea
Diversinervus elegans
Bothriophryne ceroplastae Comp. (Encyrtidae)
Anicetus parvus Comp. (Encyrtidae)
Coccidoxenus ugandensis Comp. (Encyrtidae)
Cerapterocerus inutilis Comp. (Encyrtidae)
Coccophagus isipingoensis Comp.

The species of *Scutellista* obtained was considered by Compere (107) to exhibit only a rather trivial difference from *Scutellista cyanea* bred from black scale.

The parasite species bred from white wax scales in Uganda and Kenya were largely different, though four species were common to both areas. In Kenya, *Scutellista cyanea* and *Diversinervus elegans* were the most important parasites, and the most promising species in Uganda was *Bothriophryne ceroplastae.*

Attempts to breed the imported parasites were impeded because the scales were not in the right stage when the parasite adults were available. Attempts were made to breed sixteen of the species imported, but only *Scutellista cyanea*, *Diversinervus elegans* and *Bothriophryne ceroplastae* were bred on *Ceroplastes destructor* in Australia, and the numbers reared were small. *Scutellista cyanea* were also bred on *Saissetia oleae*. The only parasites liberated were one hundred and ninety-six *Scutellista cyanea* (1935–8) and forty-nine *Diversinervus elegans* (1936–8). Neither became established on *Ceroplastes destructor*.

Prior to these liberations, *Scutellista cyanea* was common in New South Wales as a parasite of black scale, but had not been recorded from wax scales, and evidently there are biological forms of this species. Apparently the Kenya form has not become established on white wax scale although there is a recent record of an adult *Scutellista cyanea* being found beneath an Indian white wax scale in New South Wales. *Diversinervus elegans* had been obtained in Queensland and New South Wales from *Saissetia oleae* and *Saissetia nigra* (Nietn.) before the above liberations were made.

At the time of this investigation, the white wax scale on coffee in Kenya was considered to be *Ceroplastes destructor*. De Lotto (128) has recently concluded that this insect is a new species *Ceroplastes luteolus* De L., but that *Ceroplastes destructor* occurs in Kenya as an uncommon insect on *Gymnosporia*.

Natural enemies of white wax scale in Australia include *Orcus chalybeus* in New South Wales, and *Tomocera californica* and *Rhizobius ventralis* in Queensland.

C.S.I.R.O. has recently renewed the attempt at the biological control of white wax scale.

Sources
41, 97 (1953–7), 105, 107, 128, 246, 321, 402 (1935–6), 403 (1949–51), 497.

(10) **Pink wax scale**—*Ceroplastes rubens* Mask. (Coccidae, Hem.)

Ceroplastes rubens is a major pest in Queensland and is of some importance also in New South Wales. It attacks citrus and other fruit trees, and occurs on many other hosts. It was originally described from Queensland, but Froggatt suggested that it may have been introduced from Ceylon.

As early as 1897, Tryon (515) proposed that *Tomocera californica*, *Coccophagus* sp., and a parasite of *Ceroplastes floridensis* should be introduced from Hawaii for the control of pink wax scale in Queensland.

C. P. Clausen (unpublished parasite index) has the following records of parasites introduced into Australia against the pink wax scale:

	Introduced	
Parasites	Origin	Year
Chalcidoidea spp.	Hawaii	1899
Tomocera ceroplastis Perk.	China	*c.* 1896

These parasites were possibly introduced into Queensland. Perkins (461) considered that *Tomocera ceroplastis* was certainly imported from China into North Queensland, and he recorded that it was parasitizing *Ceroplastes ceriferus* in central and northern Queensland at that time.

The New South Wales Department of Agriculture introduced and liberated in 1901 specimens of *Tomocera californica* and of a species of *Coccophagus* which had rendered *C. rubens* "quite harmless in Honolulu". Apparently this species of *Coccophagus* was a parasite found by Koebele in Japan on *Ceroplastes rubens* (99) and was possibly *Aneristus ceroplastae*, a parasite of *Ceroplastes* spp., *Saissetia* spp. and *Coccus* spp., that has been recorded as a parasite of *Coccus elongatus* (Sign.) (*longulus* Dougl.) in New South Wales.

Tomocera californica is probably of Australian origin although it was described originally from Californian material. It was introduced into Western Australia from New South Wales in 1902 for the control of black scale.

Recently, C.S.I.R.O. began work on the biological control of *Ceroplastes rubens* and, in 1955, introduced *Anicetus beneficus* Ish. and Yasum., a parasite of *C. rubens* from Japan, but a culture was not established, and this insect was not released. The investigations are continuing.

In Queensland, the following natural enemies of pink wax scale have been recorded: *Catoblemma dubia*, *Rhizobius ventralis*, *Scymnus notescens* Blackb., *Scymnus* sp., *Leis conformis*, *Cryptolaemus montrouzieri*, *Chrysopa signata* Schneider, *Aspidiotiphagus australiensis* Gir.(Eulophidae), *Metaphycus varia* Gir. and *Physcus atrithorax* Gir.(Eulophidae).

Sources
72, 79, 97 (1954–7), 99, 106, 175, 202, 232, 239, 402 (1901), 403 (1950–1), 461, 486, 497, 515.

(11) **San Jose scale**—*Quadraspidiotus perniciosus* (Comst.) (Diaspididae, Hem.)

This scale, which is thought to have originated in China, is not a major pest in Australia, but it is of some importance on apricot, apple, plum, peach and other hosts in the eastern States and in Western Australia. It is not known to occur in South Australia (80).

San José scale was first recorded in Western Australia in 1897. Its appearance caused great anxiety, and stringent control measures were adopted; infested trees were grubbed and burned (317), but the pest was not eradicated. San José scale has not proved to be as serious a pest in Western Australia as it is in Europe and America. Jenkins (319) considers that probably it has not become a major pest in Western Australia for climatic reasons, the relatively long dry summer may be unfavourable for its reproduction. Although the relative lightness of San José infestation has sometimes been attributed to parasites and predators, Jenkins considers that there is little evidence to support this. On the other hand (C. F. H. Jenkins, personal communication), it has been suggested that the use of DDT for the control of codling moth at Bridgetown, Western Australia, may have contributed to a recent increase in San José scale.

The Department of Agriculture made several attempts to establish natural enemies of this scale insect in Western Australia. Two attempts to introduce hymenopterous parasites from California in 1907 were unsuccessful, and two introductions of parasites from Pennsylvania, reported in 1915, were also unsuccessful, no specimens arriving alive. Earlier, the following two coccinellid predators of *Aspidiotus* had been introduced. *Chilocorus circumdatus* was imported from Hong Kong in 1902: it was released, but not established. In 1903, an unidentified coccinellid was obtained at Seville, Spain, and G. Compere recommended its release on red scale, San José scale or greedy scale. It was liberated on red scale, but apparently did not become established.

A species identified as *Aphelinus fuscipennis*, the name formerly in use for the common parasite of red scale, *Aphytis chrysomphali*, has been recorded as a parasite of San José scale in Western Australia.

In New South Wales, natural enemies of San José scale are common, but they do not reduce the scale to a level that renders chemical control unnecessary. The natural enemies of the scale in this State include *Aspidiotiphagus australiensis*, *Coccinella repanda*, *Rhizobius debilis*, *Batrachedra sparsella* Walk., and a cheyletid mite.

The New South Wales Department of Agriculture in 1927 introduced *Chilocorus stigma* for the control of San José scale, but the predator was not recovered.

In Queensland, the following natural enemies of this pest have been recorded: *Orcus australasiae*, *Orcus chalybeus*, *Rhizobius hirtellus* Crotch, *Batrachedra* sp., and *Coccophagus clariscutellum fasciafacies* Gir.

Sources
16, 42, 80, 203, 206, 239, 311, 317, 319, 542 (1920–1, 1923–4).

(12) **Coconut scale**—*Aspidiotus destructor* Sign. (Diaspididae, Hem.)

The coconut scale is a serious pest in the Ninigo Group and other coral islands in the north-eastern portion of the Territory of New Guinea. In 1928–9 parasites of coconut scale were collected and despatched to one of the Western Islands where the scale infestation was serious. In the same year several batches of coccinellids were sent to Pelleluhu Island where these predators seemed to be absent, and reports indicated that they had some beneficial effect.

Source
502 (1928–9).

(13) **Mealy bugs** (Pseudococcidae, Hem.)

At the beginning of the century mealy bugs were very destructive pests of citrus in Western Australia. The species concerned were at that time given as *Dactylopius citri* and *D. adonidum* L. These and mealy bugs identified as *D. destructor* Comst. and *D. longifilis* Comst. were pests also on other outdoor and glasshouse plants. Reliable names for these mealy bugs cannot be given. In the world literature *D. destructor* and *D. longifilis* are usually taken to be synonyms of *Planococcus citri* (Risso) and *Pseudococcus adonidum* (L.) (*longispinus* Targ.) respectively.

To control these mealy bugs, two predators were introduced into Western Australia, *Cryptolaemus montrouzieri* from New South Wales in 1902, and an unidentified coccinellid from Malaga, Spain, in 1903. Both species were liberated, but apparently only *Cryptolaemus montrouzieri* was established. This predator rapidly became an important factor in the control of mealy bugs in Western Australia, and its introduction is regarded as an outstanding biological control success.

Forte (178) stated that the mealy bug that was first recorded on grape-vine in Western Australia by Lea in 1898, still causes serious damage to vines in some seasons, the periodic outbreaks being attributed to fluctuations in the abundance of host and predators (*Cryptolaemus montrouzieri* and chrysopids). Forte used the name *Pseudococcus maritimus* (Ehr.) for the species concerned, but specimens recently collected from grape-vines in the same locality were identified by H. M. Brookes (personal communication) as *Ps. adonidum.*

The long-tailed mealy bug (*Ps. adonidum*) has been recorded as a serious pest on citrus, pears, and grape-vines in the commercial orchards of the River Murray irrigation areas, and the citrus mealy bug (*Planococcus citri*) is a serious pest in hothouses and shade-houses in South Australia (80). There is, however, a relative freedom from mealy bug pests in Australia, which is attributable to the control exercised by natural enemies.

In Queensland, *Ps. adonidum* never occurs in large numbers and cannot be considered a pest of citrus. Artificial control of mealy bugs on citrus in Queensland is rarely required. Large colonies are generally the result of a temporary absence of natural enemies, especially of *Cryptolaemus montrouzieri* (497).

In New South Wales, the grape-vine mealy bug (*Pseudococcus* sp.) is heavily attacked by natural enemies, including parasites, coccinellids and lacewings, which normally keep it under control (268).

In New Guinea, *Planococcus citri* has recently caused considerable damage to *Coffea arabica* on one of the plantations at Wau. *Cryptolaemus affinis* Crotch. (thought at the time to be *C. montrouzieri*) was introduced from the Markham Valley in 1957 for its control. It is intended also to introduce *C. montrouzieri* from Australia into the coffee plantations of the Western Highlands where mealy bugs appear to cause much injury to shade trees (J. J. H. Szent-Ivany, personal communication).

The following natural enemies of mealy bugs have been recorded in Australia:

Pseudococcus acaciae (Mask.)
- ? *Catoblemma dubia*

Pseudococcus adonidum
- ? *Anagyrus* sp.
- *Anarhopus sydneyensis* Timb.(Encyrtidae)
- ? *Leptomastix* sp. (Encyrtidae)
- *Coccophagus gurneyi* Comp.
- *Cryptolaemus montrouzieri*
- *Callineda testudinaria*
- *Chrysopa ramburi* Schneider

Pseudococcus albizziae (Mask.)
- Encyrtid
- ? *Chaetoleucopis dactylopivora* Mall.(Ochthiphilidae)

Pseudococcus aurilanatus (Mask.) (*Nipaecoccus aurilanatus* (Mask.))
- *Pachyneuron* sp. (Pteromalidae)
- *Tetracnemus* sp. (Encyrtidae)

Encyrtid
Cryptolaemus montrouzieri
Planococcus ? *citri* (Risso)
Leptomastidea (*Paraleptomastix*) *abnormis* (Gir.) (Encyrtidae)
Pseudococcus gahani Green
Coccophagus gurneyi
Tetracnemus pretiosus Timb.
Cryptolaemus montrouzieri
Cleodiplosis koebelei (Felt) (Cecidomyiidae)
Scymnus sp. (*Pullus, Diomus*)
Chrysopa sp.
Pseudococcus spp.
Pseudoleucopis flavitarsis Mall.(Ochthiphilidae)
Cryptolaemus montrouzieri
Midus pygmaeus Blackb.(Coccinellidae)
? *Anagyrus* sp.
? *Leptomastix* sp.

H. M. Brooks (personal communication) has reared the following parasites from material collected in South Australia:

Pseudococcus near *comstocki* (Kuwana)
Anagyrus sp.
Ophelosia crawfordi Riley(Pteromalidae)
Aphycus sp.
Tropidophryne flandersi Comp.(Encyrtidae)
Myiocnema comperei
Thysanus sp. (Thysanidae)

Sources
18, 62, 63, 80, 98, 99, 133, 134, 135, 136, 137, 175, 178, 206, 212, 268, 277, 317, 403 (1947–9, 1953–4), 407, 411, 417, 421, 497, 502 (1956–7), 532, 540.

(14) Other Coccoidea

There are other well-known coccid pests in Australia which are more or less satisfactorily controlled by parasites and predators. Summerville (497) has commented that the great majority of parasites of the citrus scales, of proven outstanding value which would be expected to become acclimatized in Queensland, are well distributed throughout the State. Many are indigenous and most of the remainder have been imported accidentally. He considered that, of fourteen coccids on citrus in Queensland, worthwhile results from the introduction of further natural enemies were likely to be obtained only with *Ceroplastes rubens.*

Among the important coccid pests of citrus which are more or less effectively controlled by natural enemies in Queensland are:

Circular black scale, *Chrysomphalus ficus.*
White louse scale, *Unaspis citri.*
Hemispherical scale, *Saissetia coffeae* (Walk.).
Cottony cushion scale, *Icerya purchasi.*

Another scale which is normally kept under control by parasites and predators is *Diaspis bromeliae* (Kern.), the pineapple scale, which only occasionally causes important damage to pineapple crops.

Sources
77, 78, 470, 497.

(15) Apple leafhopper—*Typhlocyba froggatti* Baker (Cicadellidae, Hem.)

The apple leafhopper is a pest of some importance on apple in all the Australian States. Probably a native of Europe, it was first recorded in Australia in 1918. It spread to Tasmania about 1929, and

after causing damage in Tasmania, New South Wales and South Australia for some years, the first serious outbreaks in Victoria occurred in 1935–6. The leafhopper extended its range into the Stanthorpe district of Queensland in 1937–8, and reached Western Australia in 1942.

The Tasmanian Department of Agriculture introduced from New Zealand in 1935 the egg-parasite, *Anagrus armatus nigriventris* Gir.(Mymaridae). This parasite was liberated each season until 1941 in Tasmanian orchards and became established quite rapidly in all the principal apple areas. By 1943, 80–90 per cent. of the overwintering host-eggs were regularly parasitized in the orchards where it was established. By 1947, *Typhlocyba froggatti* had not been a serious problem in such areas for several years.

Apple leafhopper eggs parasitized by *Anagrus armatus nigriventris* were brought from Tasmania and placed in Blackwood orchard, South Australia, in 1940. It is not known if the parasite became established (D. C. Swan. personal communication).

From Tasmania, *A. armatus nigriventris* was introduced into Western Australia in 1943 and 1947–8, but did not become established. In Western Australia, severe infestations have occurred, but there has been some diminution in the importance of the pest in this State, and this has been attributed to the more general use of DDT for its control.

A. armatus nigriventris has not yet been introduced into the other States, where apple leafhopper is controlled by insecticides. With the introduction of DDT for the control of codling moth on apple in Tasmania, a marked increase in leafhopper populations was observed, although the leafhopper is very susceptible to DDT. There is reason to fear that this resulted from the adverse effect of DDT on the populations of *A. armatus nigriventris*.

The present result of this attempt at the biological control of apple leafhopper appears to be a diminution of the importance of the problem in Tasmania.

It has been suggested that apple leafhopper may be less abundant in neglected orchards: in the absence of pruning little new wood is produced in the ensuing season, and such wood may well be impervious to the ovipositor of the leafhopper (162).

Sources
162, 165, 166, 170, 315, 317, 378, 381, 501 (1934–41, 1947–8).

(16) **Codling moth**—*Cydia pomonella* (L.) (Olethreutidae, Lep.)

Cydia pomonella is a major pest in all States except Western Australia. Little work on its biological control has been carried out in Australia, chiefly because investigations overseas have not been encouraging.

The introduction of a parasite of codling moth into Western Australia was planned in 1903 (137). This parasite was *Ephialtes caudatus* (Ratz.) (Ichneumonidae) which was imported into California from Spain under the name of *Calliephialtes messor* (Grav.) in 1904–5. It has been reported (328), possibly erroneously, that this parasite was actually introduced from California into Western Australia.

The Queensland Department of Agriculture and Stock imported *Trichogramma minutum* Riley from California in 1927, intending to mass-breed the parasite for the control of codling moth. *T. minutum* was liberated in 1928, and some recoveries were made from codling moth eggs shortly afterwards in 1929. However, the introduction was without value.

T. minutum was also introduced by the New South Wales Department of Agriculture from California in 1928, and the parasite was released.

C.S.I.R. investigated in England the possible usefulness of *T. minutum* and *T. evanescens* Westw. in controlling codling moth, and imported stocks of *T. minutum* in 1929 and 1930. However, no liberations were made as the investigations indicated that the parasite would not be able to control *C. pomonella*.

It is not known whether the liberation of *T. minutum* in Queensland and New South Wales led to the establishment of the imported 'strains': before these introductions Girault had reported the presence of *T. minutum* on other hosts in four of the mainland States.

Of the parasites attacking *Cydia pomonella* in Australia, the most important is apparently *Trichogramma australicum* Gir., which has been reported to effect a partial check on codling moth in the late summer. Other parasites recorded from codling moth in Australia are *Gambrus stokesi* Cam. (Ichneumonidae), *Antrocephalus pomonellae* Cam.(Chalcididae), *Goniozus antipodum* Westw.(Bethylidae), *Perisemus* sp.(Bethylidae), *Parasierola* sp.(Bethylidae), *Dibrachys australis* Gir.(Pteromalidae), *Pteromalus* sp., ichneumonids, and tachinids. Various predators have also been reported. These include *Leis conformis*, soldier beetles, ground beetles, and reduviid and pentatomid bugs. In Victoria, a fungus, *Isaria farinosa* (Dicks.) Fr., has been reported to kill 90 per cent. of codling moth caterpillars in one area, and this fungus kills large numbers of the caterpillars in Tasmania in moist seasons.

Sources
3, 116 (1927–31), 137, 159, 211, 328, 368, 376, 469 (1927–31), 501 (1919–20), 527.

(17) **Oriental fruit moth**—*Cydia molesta* (Busck) (Olethreutidae, Lep.)

Cydia molesta is an important pest of peach and other fruits in Victoria and New South Wales. The cosmopolitan *Dibrachys cavus* (Walk.) (*boucheanus* (Ratz.)) is an important parasite of *Cydia molesta* in Australia, parasitizing up to 90 per cent. of the overwintering larvae. Other parasites recorded from the oriental fruit moth in New South Wales and Victoria are:

Antrocephalus pomonellae
Chromocryptus antipodialis Ashm.(Ichneumonidae)
Gambrus stokesi
Perisierola angulata Mues.(Bethylidae)
Bassus sp. (Ichneumonidae)
Angitia sp. (Ichneumonidae)

Apparently the parasites of *Cydia molesta* in Australia are active only in the winter months, and C.S.I.R., therefore, attempted to establish the following parasites from the United States:

Parasites	Introduced	Liberated
Macrocentrus ancylivorus Roh. (Braconidae)	1935–9	1935–40
Glypta rufiscutellaris Cress.(Ichneumonidae)	1935–7, 1939	1935–8
Agathis (*Bassus*) *diversus* (Mues.)	1937	1937–9
Ascogaster quadridentata Wesm. (*carpocapsae* Vier.) (Braconidae)	1937	1937–8
Horogenes (*Inareolata*) *molestae* (Uchida)	1937, 1938	1937–9
Macrocentrus delicatus Cress.	1938	1938–9

The parasite liberations were made principally in the Shepparton district of Victoria, but also in the Murrumbidgee Irrigation Area of New South Wales. The numbers liberated were, except for *Macrocentrus ancylivorus*, rather small. Of the species liberated, only *M. ancylivorus*, *Agathis diversus*, and *Glypta rufiscutellaris* were recovered, and only *M. ancylivorus* was recovered after 1938. *M. ancylivorus* has not been collected since 1939–40, and it is considered that none of the introduced parasites became established.

The failure to establish *M. ancylivorus* may have resulted from the long warm autumns and the lack of alternative hosts on which the parasite could overwinter. *Glypta rufiscutellaris* requires an alternative host to carry it through its life-cycle, and it was not expected that this parasite would become established.

All the parasite species which appeared to offer any promise of controlling *C. molesta* were released in Australia, and the work ceased when it seemed that none could be established.

Sources
51, 116 (1934–43), 236, 265, 266, 388, 402 (1936–7).

(18) **Banana scab moth**—*Nacoleia octasema* (Meyr.) (Pyralidae, Lep.)

Banana scab moth causes serious damage to bananas, a staple food of the native population, in Keravat, New Britain. This insect occurs on *Heliconia* spp. and *Pandanus* spp. on the mainland of New Guinea; on banana and *Heliconia* in New Britain; and on banana in Fiji, where *Heliconia* does

not appear to be attacked. It seems that races of *Nacoleia octasema* with different host-ranges occur in these areas.

R. W. Paine, who was working in New Guinea on the biological control of banana scab moth for Fiji, obtained an apparently new species of *Litomastix* (Encyrtidae) from *Nacoleia octasema* on *Heliconia* and *Pandanus* in the Morobe District and at Madang, and sent several consignments of the parasite from Lae for liberation at Keravat, New Britain, in 1957. No recoveries have been recorded so far, and it appears that the species of *Litomastix* imported will not parasitize *Nacoleia octasema* on bananas in New Britain. (G. S. Dun and R. W. Paine, personal communications.)

(19) **Rhinoceros beetle**—*Oryctes rhinoceros* L. (Scarabaeidae, Col.)

Oryctes rhinoceros appears to have been introduced into New Guinea at the time of the Japanese occupation during the last war, and has become a major pest of coconut plantations. It is as yet of limited distribution in the Bismarck Archipelago, being established on the Gazelle Peninsula of New Britain and, to a lesser extent, in parts of New Ireland.

Damage is caused to the crown of the coconut palm, which is sometimes killed directly or by the entry of secondary organisms. In addition, the palms are damaged by two indigenous rhinoceros beetles, *Scapanes grossepunctatus* Stern. and *S. australis* Boisd., and the elephant beetle, *Dynastes gideon*.

The Department of Agriculture has introduced two parasites of other species of *Oryctes*, *Scolia oryctophaga* Coq.(Scoliidae) from Mauritius in 1952 and 1953, and *S. ruficornis* F. from Zanzibar in 1952. Both were liberated in New Britain in 1952, and further liberations of *S. oryctophaga* were made in 1953.

S. ruficornis is well established in the Kokopo area near Rabaul, where it is now possible to replant coconuts, which was not possible prior to the establishment of the parasite. Collections of *S. ruficornis* were made in this locality in 1957 and liberated in other areas. *S. ruficornis* is also established on the Keravat Agricultural Station, but it is not in sufficient numbers to permit palms to be planted successfully (G. S. Dun, personal communication).

Several predators have also been introduced for the control of *Oryctes rhinoceros*. In 1952, *Pachylister* (*Platylister*) *chinensis* (Quens.) (Histeridae) was introduced from Fiji and liberated, but is not yet established. Although primarily a predator of dipterous larvae, this species will readily attack first and early second stage larvae of the rhinoceros beetle. More recently, several species of *Leionota* (Histeridae) and of *Pyrophorus* (Elateridae) were introduced from Trinidad. These are predators which occur in rotting coconut trunks or similar locations. Eggs of a reduviid predator of *Oryctes*, *Platymeris rhadamanthus* Gerst. were imported in 1957 from Zanzibar, but none of the nymphs obtained was reared to maturity (G. S. Dun, personal communication). Attention is also being given to the native *Scolia pulchripennis* Cam., a parasite of *Scapanes grossepunctatus*.

Sources
150, 151, 152, 153, 502 (1951–3, 1954–5, 1956–7).

(20) **Banana weevil borer**—*Cosmopolites sordidus* Germ. (Curculionidae, Col.)

Cosmopolites sordidus is an exotic species which became established in Queensland (possibly from Papua) at the end of the nineteenth century, and rapidly became the most serious pest of bananas in Queensland. It is also present in the Tweed River area of New South Wales, where it was accidentally introduced from Fiji about 1914–5.

The adults and larvae of *Plaesius javanus* Er.(Histeridae) are predatory on the larvae and pupae of *Cosmopolites sordidus*, *Rhabdoscelus obscurus* Boisd.(Curculionidae), and other Rhynchophora on palms and bananas in the East Indies. *Plaesius javanus* was introduced from Java by the Queensland Department of Agriculture and Stock in 1921–4, 1926, and 1928, and was liberated in a number of years from 1921–8. There was little evidence of establishment until recoveries were made, after the 1928 liberations, in the Cooran district of the near north coast. However, these colonies died out after a few years. *Plaesius javanus* was also introduced by the New South Wales Department of Agriculture from Java in 1922 and from Fiji in 1934, but it did not become established.

Chrysopilus ferruginosus Wied.(Leptidae), the larvae of which are predatory on the larvae and pupae of *Cosmopolites sordidus*, was introduced into Queensland by the Department of Agriculture and Stock from Java in 1928 and was liberated, but it failed to become established. This predator was not considered to be as important as *Plaesius javanus*.

Dactylosternum hydrophiloides Macl.(Hydrophilidae) was introduced, by C.S.I.R. in conjunction with the Queensland Department of Agriculture and Stock, from Malaya in 1938 and 1939. It was liberated in Queensland in 1939, and was established in the southern coastal areas. It increased rapidly, and was distributed to other localities. There seems reason to believe that it is of some value, but it has by no means solved the banana weevil problem. It was also liberated in New South Wales in 1939.

Sources
40, 116 (1940–1), 186, 187, 188, 189, 190, 228, 358, 370, 389, 469 (1914–6, 1925–31, 1938–41, 1947–8), 470, 489, 524, 525, 527, 538, 539.

(21) **Cacao weevil borer**—*Pantorhytes plutus* Obert. (Curculionidae, Col.)

Pantorhytes plutus attacks cacao in the Bismarck Archipelago, and related species are associated with cacao on the New Guinea mainland. A dryinid parasite of *P. plutus* and the cacao longicorn, *Glenea aluensis* Gah.(Cerambycidae), has been investigated, but there is little hope of the parasite being used effectively against them.

Source
152.

(22) **Coconut leafminer**—*Promecotheca papuana* (Csiki) (Hispidae, Col.)

In New Guinea, *Promecotheca papuana* is ordinarily a minor pest kept under control by its indigenous parasites, but where the normal overlapping of host generations is prevented by the hay itch mite, *Pyemotes ventricosus* (Newp.) (Tarsonemidae), the parasites are prevented from functioning effectively. In consequence, *Promecotheca papuana* prior to the war caused serious damage to coconut plantations and native groves in the western end of New Britain at several points on the north and south coasts in areas of extremely heavy rainfall. Parasite liberations were made to cope with outbreaks.

In 1937–8, *Eurytoma* sp. (Eurytomidae), a larval parasite occurring in New Britain, was bred and distributed in those localities where parasites were slow to appear.

Pleurotropis parvulus Ferr.(Eulophidae), a larval and pupal parasite which attacks *Promecotheca reichei* in Java, was successfully imported in 1938 from Fiji, previous attempts at the introduction from Fiji and the New Hebrides in 1937 having failed. The parasite was cultured and was liberated (1938–9) in the Rabaul-Kokopo area, Gasmata, Talasea, Linga-Linga, the Manus District, and the Namatanai district in New Ireland. It was established readily in most areas. In the Rabaul district, the introduction of *Pleurotropis parvulus* reduced the host permanently to an insignificant level. However, at Linga-Linga, on the north coast of New Britain, the parasite has not been entirely effective, and several outbreaks have occurred since its introduction. At Lindenhafen, on the south coast, it was entirely effective until an outbreak in 1953–4.

Planters in New Guinea have long employed the predatory green tree ant, 'Kurukum', *Oecophylla smaragdina* (F.) (Formicidae), to help control *Promecotheca papuana*. Nests of these tree ants are placed in the crowns of the palms, and cane ropes are run from palm to palm to enable the ants to spread without having to reach the ground. The value of the method has been disputed as the ants transport and protect aphids, scale insects and mealy bugs.

Sources
150, 152, 153, 193, 197, 199, 397, 449, 502 (1937–40).

(23) **Coconut leaf Hispa**—*Brontispa longissima* Gestro (*froggatti* Sharp) (Chrysomelidae, Col.)

Brontispa longissima occurs throughout the Territory of New Guinea, but it is a pest of coconut palms principally in the Kieta district. There are a number of indigenous parasites, but in 1939

Tetrastichus (*Tetrastichodes*) *brontispae* Ferr., a larval and pupal parasite of Javanese origin, was introduced from the British Solomon Islands, bred in the laboratory, and liberated in New Britain, New Ireland, Manus, Kieta, and Rabaul. It was recovered in the Rabaul area, but there is no evidence that it has had much effect on the importance of the host, which however is not now much of a problem.

Sources
150, 199, 349, 400, 401, 450, 502 (1939–40).

(24) **Pear and cherry slug**—*Caliroa cerasi* L. (*limacina* (Retz.) (Tenthredinidae, Hym.)

Caliroa cerasi is a pest of minor to moderate status in all the States of Australia except Queensland, where it is either absent or rare. Little work has been carried out on its biological control because, although the pear and cherry slug is troublesome, it is easily controlled by sprays.

The New South Wales Department of Agriculture introduced cocoons of *Caliroa cerasi* from England in 1928, the material originating in northern France and possibly England. The cocoons were thought to be parasitized by:

Mesoleius caninae Bridgm.(Ichneumonidae)
Mesoleius dorsalis Grav.
Polyblastus phygadeuontoides Kriech.(Ichneumonidae)
Perilissus luteolator Grav.(Ichneumonidae)

The parasites issued too late to attack pear slug in the field, and emerged chiefly during the following winter. It is uncertain whether any parasite liberations were made, but *Polyblastus phygadeuontoides* may have been liberated. In any event, no parasites became established. A further consignment of hosts collected in northern France was imported into New South Wales in 1931. These were believed to be parasitized by *Polyblastus phygadeuontoides*, but no parasites emerged from this material (S. L. Allman, personal communication).

Sources
35, 402 (1928–9).

(25) **Queensland fruit fly**—*Strumeta tryoni* (Frogg.) (Trypetidae, Dipt.) and **Mediterranean fruit fly**—*Ceratitis capitata* (Wied.) (Trypetidae, Dipt.)

Though several other fruit flies sometimes cause economic damage to fruit in Australia, *Strumeta tryoni* and *Ceratitis capitata* are the major fruit fly pests. Queensland fruit fly is a major pest in Queensland and New South Wales, and its appearance in recent years in Victoria and South Australia has caused concern. The Mediterranean fruit fly is serious in Western Australia, where it first appeared in 1895. It was first recorded in New South Wales in 1898, and for some years was the common pest species in that State. However, it was later replaced by the Queensland fruit fly and is now never seen in New South Wales.

Ceratitis capitata appeared in the suburbs of Adelaide, South Australia, in 1948–50, but it was eradicated. It appeared in 1957 at Port Augusta, when eradication procedures were undertaken. *Strumeta tryoni* has occurred in small foci in the Adelaide suburbs in most years during the last decade. There is strong evidence that usually these outbreaks are begun by independent introductions by travellers (D. C. Swan, personal communication).

Natural enemies	Introduced	
	Origin	Year
Parasite spp.	India	1903
Pseudeucoila (*Hexamerocera*) *braziliensis* (Ashm.) (Cynipidae)	Brazil	1904
Staphilinid spp.	Brazil	1904
Opius cereus Gah.(Braconidae)	Brazil	1904
Opius bellus Gah.	Brazil	1904
Staphilinid spp.	Brazil	1905
Parasites (several)	India	1906
Syntomosphyrum indicum Silv.(Eulophidae)	India	1907
Larval parasites (2 or more)	India	1907
Opius tryoni Cam.	Queensland	1909, 1913
Tetrastichus giffardianus Silv.	Fiji	1936

An attempt to eradicate the Mediterranean fruit fly from Western Australia was made in 1901 by picking and boiling all green fruits. When the attempt failed, an overseas search for natural enemies was initiated in 1903 and continued intermittently for some years. The above table lists, as fully as the records permit, the parasites and predators introduced into Western Australia.

It is thought that *Pseudeucoila braziliensis* is the correct name for a species which has been referred to in the literature as a staphilinid, *Huamerocera braziliensis*. This error has been corrected by E. O. Essig (personal communication).

The parasites obtained from India in 1903 were destroyed by quarantine fumigation in India, and probably several other species imported were not released. Many of the species were released in small numbers. Those known to have been liberated are the staphilinid beetles introduced in 1904 and 1905, two unnamed species (probably *Opius cereus* and *Opius bellus*) imported from Brazil in 1904, parasites imported from India in 1906, *Syntomosphyrum indicum* (250,000 liberated in 1908–10), a braconid imported from India in 1907, *Opius tryoni*, and *Tetrastichus giffardianus*. *Syntomosphyrum indicum* and the braconid were recovered in the field, but so far as is known not one of the species introduced was established.

The New South Wales Department of Agriculture has made the following fruit fly parasite introductions:

	Introduced		
Parasite	Origin	Year	Liberated
Tetrastichus giffardianus	Hawaii	1928–9, 1932–3	1932, 1933
	Fiji	1936	1936
Opius humilis Silv.	Hawaii	1928–9, 1932–3	1932
Opius fletcheri Silv.	Hawaii	1928–9	
Opius fullawayi Silv.	Hawaii	1932–3	1933
Opius tryoni	Hawaii	1932–3	1932–3
Opius persulcatus Silv.	India	1935	
Opius incisi Silv.	India	1935	
Opius spp. n. (2)	India	1935	
Syntomosphyrum indicum	India	1935–7	1937, 1938

Of these introduced species, *Tetrastichus giffardianus*, *Opius fullawayi*, *Opius humilis*, *Opius tryoni* (a native Australian species), and *Syntomosphyrum indicum* are recorded as being liberated in New South Wales. Attempts to breed the species imported in 1935 (*Opius persulcatus*, *Opius incisi* and two new species of *Opius*) on *Strumeta tryoni* were not successful. *Opius* adults of the *persulcatus* group were bred from fruit fly in New South Wales in 1954–5 (G. J. Snowball, personal communication). In 1937 and 1938, *Syntomosphyrum indicum* obtained from New South Wales were liberated in Queensland. It is believed that none of these alien species introduced against *Strumeta tryoni* and *Ceratitis capitata* was established.

In Queensland, *Strumeta tryoni* is attacked by two native braconids (*Opius tryoni* and *O. kraussi* Full.) and possibly by two other native species (*Opius* sp. ? *africanus* Szep. and *O. fletcheri*). Parasitism of fruit flies by native species is of little economic importance, and parasitism of fruit fly in commercial fruit is comparatively rare (365).

Following the establishment in Hawaii of various Asiatic parasites for the control of the oriental fruit fly, *Dacus dorsalis* Hend., C.S.I.R.O. renewed the attempt at the biological control of *S. tryoni*, and imported the following species:

	Introduced		
Parasite	Origin	Year	Liberated
Opius oophilus Full.	Hawaii	1952, 1954–7	1956, 1957
Opius vandenboschi Full.	Hawaii	1952	
Opius longicaudatus (Ashm.)	Hawaii	1952, 1953	1956, 1957
Opius longicaudatus (Ashm.) var. *taiensis* Full.	Hawaii	1953	

In the laboratory all these parasites, except possibly *Opius vandenboschi*, have been cultured on *Strumeta tryoni*. Small numbers of *Opius oophilus* and *Opius longicaudatus* have been recovered in the

field, but so far there is no reason to believe that these species are established. A C.S.I.R.O. officer was sent to Hawaii at the end of 1957 to organize the large-scale dispatch of fruit fly parasites to Australia for liberation during the following year. The work is continuing.

There are many factors which may have contributed to the failure so far of attempts at the biological control of fruit flies in Australia. Some of the natural enemies were released in very small numbers, and many were released without determining whether they were able to parasitize the species they were meant to control. Technical difficulties in importing and breeding fruit fly parasites, the absence of hosts at the time of liberation or during the winter months after liberation, possibly all hindered the satisfactory development of the work. Nevertheless, it may be that the difficulty is more fundamental, that the increase in fruit size resulting from cultivation has so reduced the capacity of larval parasites to make contact with their hosts, that adequate biological control of fruit flies in commercial crops by parasites which oviposit in the host larvae is generally not practicable.

Sources

4, 25, 26, 27, 64, 95, 97 (1951–7), 100, 101, 103, 115, 136, 158, 214, 221, 233, 245, 276, 317, 359, 365, 402 (1928–9, 1932–3, 1935–6, 1937–8), 407, 408, 409, 410, 411, 413, 417, 445, 469 (1913–4, 1937–8), 481, 482, 533 (1948–9), 542 (1907–11, 1913–4).

B. GARDEN AND FIELD PESTS

(26) **Grasshoppers**—(Acrididae, Orth.)

The fungus *Empusa grylli* Fres.(Entomophthoreae) was recorded from locusts in Australia as early as 1907 during a locust plague in New South Wales (369). This fungus, under the name 'South African locust fungus', had attracted much attention some years earlier. It was at first thought to be capable of being artificially cultivated on gelatine and disseminated for locust control, and culture tubes said to contain this fungus were sent to Australia and other countries. However, the fungus present was actually *Mucor racemosus* Fres.(Mucoraceae). The error arose from the fact that, though the fungus that killed the locusts in South Africa was *Empusa grylli*, it was the *Mucor* present on the dead locusts which was cultured and distributed.

Mucor racemosus was imported from South Africa into Victoria in 1899, and into Queensland in 1898 and 1904. Arrangements were made in 1901 for its introduction from South Africa into New South Wales. From Victoria, cultures of *Mucor* were apparently sent to Queensland, New South Wales, Tasmania, and Western Australia.

In Victoria, *Mucor racemosus* was cultured and distributed to farmers from 1899 until about 1904. The fungus was disseminated by dipping live locusts in a suspension of the fungus and releasing them among locust swarms. Claims were made that the fungus was effective, especially in the cooler and more mountainous areas.

In New South Wales, *Mucor* was distributed from 1900 until 1903. It was concluded that the fungus was generally ineffective and much too uncertain in its results. Possibly, in both Victoria and New South Wales, the presence of *Empusa grylli* in the field created the impression that the liberation of *Mucor* was causing mortality in locust swarms.

Mucor was probably liberated in Western Australia also, for Despeissis (133) referred in 1902 to earlier hopes of its effectiveness in controlling locusts.

The pest species against which *Mucor* was released in the field in Australia doubtless included, among others, *Austroicetes cruciata* Sauss. and *Chortoicetes terminifera* Walk.

It was arranged in 1903 (14) to import into New South Wales cultures of the chinch bug fungus, *Beauveria* (*Sporotrichum*) *globulifera* (Speg.) (Mucedineae), which was at that time being used in the United States for the control of locusts. It is not known if the introduction actually took place, but this fungus had been introduced into New South Wales in 1901 for possible use against the Rutherglen bug (*q.v.*).

It was intended in 1902 (133) to introduce into Western Australia from New South Wales *Blaesoxipha* (*Masicera*) *pachytyli* (Skuse) (Sarcophagidae), a parasite of adult and nymphal locusts, but there is no record of this introduction having been made.

Sources

9, 14, 17, 19, 133, 137, 181, 182, 183, 201, 205, 208, 213, 215, 278, 366, 367, 368, 369, 442.

(27) **Lucerne flea**—*Smynthurus viridis* (L.) (Smynthuridae, Collem.)

Lucerne flea, an exotic species of palaearctic origin, is a pest on subterranean clover and other plants in all States of Australia except Queensland. It is a major pest in Western Australia and South Australia.

In 1931, a predator, *Biscirus lapidarius* (Kram.) (Bdellidae) was found preying on *S. viridis* and related springtails in certain localities in the south-west of Western Australia. This mite occurs in Europe, and was evidently introduced by accident into Australia.

C.S.I.R. and the State Departments of Agriculture were concerned for several years with the transfer of this predator from Western Australia to the other States. In 1933, liberations were made in South Australia, Victoria, and Tasmania, and further liberations were made in Tasmania in 1934 and in Victoria in 1936. It was liberated in New South Wales in 1935–7 and 1938–9. In Western Australia, the collection and distribution of the predator continued intermittently until 1941.

It was soon realized that *B. lapidarius* already occurred in South Australia, Victoria and Tasmania, for colonies were found in areas where no liberations had been made. The liberations of *B. lapidarius* probably did no more than hasten the spread of a predator of poor dispersal capacity into areas in which subterranean clover pastures had only comparatively recently been laid down.

As to the efficacy of the predator, the general consensus of opinion appears to be that it is of marked value in controlling lucerne flea in some areas, but that it does not generally provide an adequate degree of control. Much evidence of the effectiveness of the predator (particularly towards the end of the season) has been obtained in Western Australia, and importance has been attached to its activities in some areas in Tasmania and Victoria. In South Australia, there seems to be no proof of its usefulness. The effectiveness of *B. lapidarius* in controlling lucerne flea is probably greatly affected by physical factors.

Experiments in Western Australia showed that after top-dressing pastures with DDT incorporated in superphosphate, the lucerne flea population (which is not susceptible to DDT) increased, and that this was due to the elimination of two predatory species of *Biscirus* (*australicum* Wom. and *symmetricus* Kram.) which are susceptible to DDT.

Sources

97 (1950–1), 116 (1930–7, 1946–7), 118, 124, 125, 126, 161, 170, 313, 317, 378, 402 (1935–6, 1938–9), 420, 421, 446, 463, 499, 501 (1935–6, 1938–40), 533 (1925–32, 1933–6), 535, 542 (1931–2, 1935–40, 1941–5, 1947–8, 1950–1), 557.

(28) **Pink sugar cane mealy bug**—*Saccharicoccus sacchari* (Ckll.) (Coccidae, Hem.)

In Queensland, the Bureau of Sugar Experiment Stations attempted to introduce *Anagyrus saccharicola* Timb.(Encyrtidae) for the more effective biological control of the pink sugar cane mealy bug, *Saccharicoccus sacchari* (Ckll.). The parasite was introduced from Hawaii twice in 1935 and again in 1952–3. The first 1935 introduction failed because only females were present, and the material of the second 1935 introduction all died. *Anagyrus saccharicola* was bred from the 1952–3 introduction and was liberated, but it did not become established. This has been attributed to the fact that most of the larger mealy bugs were consumed by a plague of field mice shortly after the parasites were liberated.

Source

468 (1952–4)

(29) **Cabbage aphid**—*Brevicoryne brassicae* (L.) (Aphididae, Hem.)

Brevicoryne brassicae is an important pest of crucifers in all Australian States, and insecticides are commonly employed for its control.

In Western Australia in the period 1895–7, natural enemies of cabbage aphid reported included an ichneumonid, syrphids, and *Coccinella repanda* ab. *transversalis*, *Chilomenes quadriplagiata* and *Scymnus australasiae* Blackb. It was recorded that parasitism by the ichneumonid was heavy and the syrphids numerous, but cabbage aphid was an extremely serious pest.

The Western Australian Department of Agriculture introduced the following natural enemies of cabbage aphid:

Natural enemies	Introduced		
	Origin	Year	Establishment
Leis conformis	New South Wales, Tasmania	1896–1902	Established
Ichneumonid spp. (2)	Queensland, New South Wales	1902	
Coccinella septempunctata	Mediterranean	1903	Not established
Parasite sp.	Colombo	1907	Established
Chalcid sp.	India	1907	Established
Parasite sp.	Orient	1909	

More detailed information on the introduction of *Leis conformis* is given on p. 6 dealing with "Aphids and scale insects".

It is likely that one of the parasites introduced in 1902 was *Diaeretus rapae* (M'Intosh) (Braconidae). This parasite is common in both Western and eastern Australia.

From 1907 onwards, importance was attached in Western Australia to the control exercised by the natural enemies established. Jenkins (317) comments: "although complete success has not been obtained, the pest has been greatly reduced". The species established from Colombo was considered by Newman to be the most effective introduction.

No natural enemies have been introduced into other Australian States for the control of cabbage aphid. There is little doubt that the importance of *Brevicoryne brassicae* in many parts of Australia is substantially diminished by its natural enemies, especially the widespread and abundant *Diaeretus rapae*, which was first recorded in Australia by Ashmead in 1900. Wilson (unpublished data) found that, in the Australian Capital Territory, natural enemies provided a high degree of control of cabbage aphid when no insecticide, or lead arsenate only, was applied to cabbage crops.

Tryon considered that in Queensland a disease was more important than parasites in controlling outbreaks of cabbage aphid (in Anon, 24).

In Western Australia, outbreaks of *Brevicoryne brassicae* in inland areas have been regarded as beneficial in destroying the weeds, wild mustard and radish.

Sources
6, 22, 23, 24, 29, 62, 63, 97 (1955–7), 98, 116 (1946–7), 133, 135, 137, 170, 173, 317, 343, 384, 404, 407, 410, 411, 412, 417, 421, 470, 476, 477, 490, 541 (1896–7), 542 (1907–8, 1909–14, 1918–21, 1923–5, 1926–9, 1936–8).

(30) **Rose aphid**—*Macrosiphum rosae* (L.) (Aphididae, Hem.)

The Western Australian Department of Agriculture introduced some unidentified syrphid predators from the Philippine Islands in 1907 for the control of this aphid, but none became established.

Source
317.

(31) **Greenhouse white fly**—*Trialeurodes vaporariorum* (Westw.) (Aleyrodidae, Hem.)

Trialeurodes vaporariorum was a serious pest of tomatoes and other crops in New South Wales, Victoria, South Australia and Tasmania. It increased in importance with the development of glasshouse culture of tomatoes, the excellent breeding conditions provided by the glasshouses during the greater part of the year also increasing, by migration, the field populations.

C.S.I.R. imported *Encarsia formosa* Gahan(Eulophidae) from England in 1933 and 1934, but the consignments were not successful. From a consignment received from New Zealand in 1934 a culture was established, and liberations were made in Tasmania in 1934–5, New South Wales in 1935–6, Victoria in 1935–7 and South Australia in 1936.

In all these States, *Encarsia formosa* became established and spread with very great rapidity, and proved extremely effective. By 1939, the pest had so diminished in importance that requests

to C.S.I.R. for supplies of the parasite ceased. Though occasionally insecticides may be used to deal with infestations, this is uncommon, and the introduction of *Encarsia formosa* gave highly satisfactory control of this insect both in glasshouses and in the field.

Repeated attempts in Victoria to use *Encarsia formosa* against the azalea white fly, *Aleyrodes azaleae*, Baker and Moles, have been unsuccessful.

Sources
38, 44, 116 (1932–9), 156, 170, 377, 378, 402 (1935–7), 444, 464, 465, 513, 533 (1933–8).

(32) **Green vegetable bug**—*Nezara viridula smaragdula* (F.) (Pentatomidae, Hem.)

Nezara viridula was first reported in New South Wales in 1916, Queensland in 1917, Western Australia in 1920, Victoria in 1936, the Australian Capital Territory in 1937–8 and South Australia in 1938. It does not occur in Tasmania. It soon became a serious pest of numerous vegetable and other crops, including fruits, in all the mainland States.

In 1933, the Western Australian Department of Agriculture introduced the egg-parasite, *Microphanurus basalis* (Woll.) (Scelionidae), from Egypt. Becoming rapidly established, it was distributed for some years from 1934, especially in the south-west of the State, where *Nezara* was most serious. *M. basalis* was sent from Western Australia to New South Wales (1935), and thence to Queensland (1935), the Australian Capital Territory (1939), and Lord Howe Island (1949–50). It was introduced into South Australia from Western Australia and New South Wales (1942), and into Victoria in 1943.

In Western Australia, the importance of *Nezara* has been greatly reduced by *M. basalis*. Outbreaks still occur but they are relatively restricted. This is regarded as one of the outstanding biological control successes in Western Australia.

In New South Wales, where *M. basalis* was distributed widely until 1939, the control of the bug by the parasite in the coastal areas has been described as highly satisfactory. In inland areas the parasite has proved markedly less effective, possibly because the lower winter temperatures reduce survival from season to season. For this reason, *Nezara* remains an important pest in this State. Since DDT began to be employed for the control of this insect, requests for supplies of parasites have been renewed in some districts. In 1949–50 there were many requests for parasites from inland districts, particularly from the New England area, and at Glen Innes the bugs were numerous for the first time since the parasites were released.

In Queensland, *M. basalis* was liberated in the southern, central and northern areas until about 1939, and is widely established throughout the State. On the Darling Downs, *Nezara* has become much less abundant, though from time to time it outstrips the parasitic control. In general, the parasite does not completely control the host and outbreaks still occur. They are, however, less frequent and somewhat less injurious. *Nezara* remains a pest of some importance.

In South Australia, *M. basalis* was liberated until about 1945. It has effectively reduced the numbers of the host, and possibly the parasite has been more effective in this State than any other.

In the Australian Capital Territory, *M. basalis* is established but appears to occur in numbers that are too small to have an appreciable effect. This situation is probably common in inland areas of eastern Australia in which the winters are relatively cold.

There are no reports of the effect of the parasite on *Nezara* in Victoria.

In general, therefore, the introduction of *M. basalis* has been very beneficial, but *Nezara* is still a pest of some importance, especially in inland New South Wales. In consequence, C.S.I.R.O. has been attempting in recent years to improve the level of biological control of *Nezara* by the introduction of other parasites.

A parasite of *Nezara* adults and nymphs, *Trichopoda pennipes* (F.) (Tachinidae) had been introduced from Florida by the Western Australian Department of Agriculture in 1932 and 1933, but the material was all dead on arrival. This tachinid was introduced by C.S.I.R.O. from Florida in the years 1941–3, 1949–50, and 1952–3. Liberations were made in the Australian Capital Territory (1943, 1950, 1953), New South Wales (1950, 1953), and Queensland (1950, 1952). A variety of this

species, *pilipes* F., was introduced by C.S.I.R.O. from Montserrat (B.W.I.) in 1952–4, and liberated in Queensland and New South Wales (1952, 1953), and in the Australian Capital Territory (1953, 1954). Occasional recoveries of this species have been made, but there is no indication that it is established.

Micophanurus basalis was introduced from Montserrat (B.W.I.) by C.S.I.R.O. in 1953, and this West Indian strain was liberated in the Australian Capital Territory and all mainland States in 1953–7. An Italian strain of this species was also imported by C.S.I.R.O. in 1956, and has also been liberated in the Australian Capital Territory and all mainland States.

C.S.I.R.O. introduced another egg-parasite, *Ooencyrtus submetallicus* How.(Encyrtidae), from Trinidad in 1952 and 1953, and this species was liberated in the Australian Capital Territory and all the mainland States from 1953 until 1957. No recoveries have been made so far.

Another species imported by C.S.I.R.O. was the egg-parasite, *Ooencyrtus johnsoni* (How.) brought from Bermuda in 1953, but this species was not released.

Research on the biological control of *Nezara viridula* is continuing.

Sources
45, 50, 52, 54, 57, 84, 97 (1949–57), 116 (1941–6), 155, 317, 335, 399, 402 (1935–9, 1949–52), 403 (1948–50), 421, 422, 424, 443, 469 (1934–6, 1938–9, 1943–4), 470, 490, 491, 492 (1943–5), 527, 533 (1941–7), 534, 542 (1926–7, 1933–4, 1936–8, 1944–50), 558.

(33) **Rutherglen bug**—*Nysius vinitor* Bergr. (Lygaeidae, Hem.)

In 1901, the Department of Agriculture imported into New South Wales from the United States the chinch bug fungus, *Beauveria globulifera*, for use against the Rutherglen bug. The fungus was cultured, but there appear to be no records of its release in the field.

Source
10.

(34) **Cabbage white butterfly**—*Pieris rapae* (L.) (Pieridae, Lep.)

Pieris rapae first appeared in Australia in 1939 in Victoria. It spread rapidly, reaching Tasmania, New South Wales and South Australia in 1940, Queensland in 1942–3, and Western Australia in 1943. It quickly became a very serious pest of cruciferous crops in all States.

The pupal parasite, *Pteromalus puparum* (L.) (Pteromalidae) was imported from New Zealand by the Victorian Department of Agriculture in 1941, and was liberated in that State in 1941–4. It was recovered in 1943, and was considered to be widely established in Victoria by 1944, when up to 95 per cent. parasitism had been noted at several points (T. W. Hogan, personal communication).

The Tasmanian Department of Agriculture introduced *Pteromalus puparum* from New Zealand in 1942, and sent material to Western Australia in 1943. *P. puparum* became established rapidly in these States. It appeared in the Australian Capital Territory in 1943–4, without liberations having been made there, and was sent thence to South Australia and Victoria in 1945.

P. puparum had been recorded in Australia on several occasions from other hosts prior to its introduction from New Zealand, and this may partly account for the rapidity with which it attacked *Pieris* over a wide area in all States of Australia, except possibly Queensland.

C.S.I.R. introduced *Apanteles glomeratus* (L.) (Braconidae) from Canada in 1942, and from England in 1943–4. Material of both the North American and European strains was liberated in the Australian Capital Territory. *A. glomeratus* was sent from the Australian Capital Territory to Queensland and Victoria (1944), South Australia (1944–6), Tasmania (1949) and Western Australia (1950). It became established rapidly in all States.

C.S.I.R. imported another larval parasite, *Apanteles rubecula* Marsh., from England in 1941–2 and 1943–4, but none of this material was released. It was again imported in 1949 from Switzerland. Liberations were made in the Australian Capital Territory and New South Wales (1949–51), and Queensland, Victoria, South Australia, Western Australia and Tasmania (1950, 1951). It is established in the Australian Capital Territory and New South Wales, and possibly in South Australia. It is not established in Tasmania, and there are no records so far from the other States.

In the Australian Capital Territory, *Pieris* is very heavily parasitized by these three introduced parasites which provide a useful degree of control. In Tasmania, *Pteromalus puparum* is abundant, and *Apanteles glomeratus* is widespread, and the former undoubtedly exercises some measure of control. In South Australia, also, the introduced parasites have apparently had a markedly beneficial effect. In New South Wales in 1952–3, it was reported that a braconid (presumably *Apanteles glomeratus*) was present in most districts and appeared to be more effective than formerly. In Victoria, *Pteromalus puparum* has been credited with providing a measure of control.

The widespread use of DDT has no doubt prevented the introduced parasites from attaining their maximum effect on the abundance of *Pieris* in most areas. Whether the parasites can provide an adequate level of control of *Pieris* on the various cruciferous crops, eliminating or reducing the need for insecticidal treatments, will not be known for some time. There is reason to believe, however, that the parasites have generally reduced the abundance of *Pieris* despite the widespread use of DDT.

The large larvae of *Pieris* are difficult to kill with DDT, which is reported to provide poor control of *Pieris* in New South Wales in the late summer and early autumn. It has been suggested that the larvae have developed a resistance to this insecticide.

A virulent virus disease of the larvae of *Pieris rapae* has been discovered by C.S.I.R.O. in the Australian Capital Territory. The disease has been employed in laboratory and field experiments, and work with this disease is continuing.

Sources

49, 59, 97 (1948–57), 116 (1940–6), 129, 157, 167, 170, 171, 174, 237, 314, 317, 378, 380, 384, 402 (1949–53), 469 (1942–5, 1951–3), 470, 492 (1943–5), 495, 501 (1939–41, 1942–3, 1949–50, 1951–4), 533 (1941–2, 1943–7), 542 (1944–9).

(35) Cabbage moth—*Plutella maculipennis* (Curt.) (Plutellidae, Lep.)

Plutella maculipennis has long been a major pest of cruciferous crops in all Australian States. DDT has reduced the damage caused by *Plutella* to cabbages and cauliflowers, but fodder crops, such as turnip, rape, and chou moellier, are not usually sprayed. The control of *Plutella* is linked with that of *Pieris rapae ;* both require biological control of a high level of efficiency if the use of insecticides is to be avoided on cruciferous crops for human consumption. A lower level of biological control would be valuable for fodder crops.

In Western Australia, Lea wrote several articles in 1895–7 dealing with the natural enemies of the cabbage moth in Australia. These included various unnamed ichneumonid and chalcid parasites, and syrphid and reduviid predators. A bacterial disease was also observed.

The following unidentified parasites of *Plutella* were introduced into Western Australia by the Department of Agriculture:

	Introduced	
Parasites	Origin	Year
Spp. (2)*	New South Wales	1902
Spp. (2)	Malaga (Spain)	1903
Sp.	Colombo	1907
Sp.	India	1908
Sp.	China	1909

* It is probable that one of these parasites was *Hymenobosmina rapi* (Cam.) (Ichneumonidae), which is common in both eastern and Western Australia.

All these parasites, except possibly the last, were liberated, and it was reported that the species from New South Wales, Malaga and India were established. Between 1907 and 1926 Newman indicated on several occasions that the established parasites had had a considerable effect on the abundance of *Plutella*. Nevertheless, *Plutella* remained a pest of importance.

The Queensland Department of Agriculture and Stock found that *Trichogramma minutum* (Trichogrammatidae), which was liberated in 1928 against *Cydia pomonella*, also attacked *Plutella* in the laboratory, but it was not recovered from *Plutella* in the field.

The following parasite introductions were made by C.S.I.R.O.:

Parasites	Introduced: Origin	Introduced: Year	Liberated	Establishment
Horogenes fenestralis Holmgr.) (Ichneumonidae)	England	1936	Not liberated	
	New Zealand	1938	1938–9	Not established
Horogenes cerophaga Grav.	New Zealand	1946–7	1947–51	Established
Horogenes tibialis Grav.	Italy	1951	1951–2	?
Thyraeella collaris Grav.(Ichneumonidae)	New Zealand	1947	1947–51	Established
	Italy	1951	1951–2	Established
Apanteles plutellae Kurdj.	Italy	1951	1951–5	Established

Horogenes cerophaga and *Thyraeella collaris* were also introduced from New Zealand about 1947 by the Tasmanian Department of Agriculture.

There is some doubt about the nomenclature of the insects introduced as *Horogenes fenestralis* and *H. tibialis*, and possibly both these introductions were actually of *H. cerophaga*.

H. fenestralis was liberated in New South Wales, Victoria and South Australia. The other species were liberated on a large scale in all States.

H. cerophaga is widely established both on the mainland of Australia and in Tasmania, and is extremely abundant in many areas. *Thyraeella collaris* is established in Queensland, New South Wales, Victoria and Tasmania, at least. *Apanteles plutellae* has so far been recovered in the Australian Capital Territory, New South Wales and Queensland.

It is considered that there has been a marked reduction in the abundance of *Plutella* as a result of the parasite introductions. Reports of heavy parasitism have been made in the Australian Capital Territory, New South Wales, Tasmania and Western Australia.

With the general use of DDT and benzene hexachloride on cabbages and cauliflowers there is little opportunity in commercial market gardens for the parasites to exercise their maximum effect on the numbers of *Plutella*. It is probable that the main advantage of the parasite introductions occurs in cruciferous fodder crops. However, in experimental plots in Canberra, marketable cabbages have been grown recently with very restricted use of insecticides, and it is reported that cabbages and cauliflowers have been grown in South Australia in recent years without the use of insecticides. Work on the biological control of *Plutella* is continuing.

Sources

6, 29, 97 (1948–57), 98, 116 (1936–9, 1946–8), 131, 133, 136, 137, 157, 312, 317, 318, 343, 346, 380, 384, 407, 410, 411, 417, 421, 469 (1928–9, 1944–5, 1948–9, 1951–2), 470, 501 (1920–1, 1946–54), 541 (1896–7), 542 (1907–14, 1923–4, 1928–9, 1947–9, 1952–3).

(36) **Underground grass grubs**—*Oncopera* spp. (Hepialidae, Lep.)

Several native species of *Oncopera* are pests, principally of pastures, in Australia. The main problem is in Tasmania, where *O. intricata* Walk., *O. intricoides* Tind., and *O. rufobrunnea* Tind. are major pests, but these species are important in Victoria also. *Oncopera* species are of some importance also in South Australia and Queensland. C.S.I.R. attempted the biological control of these species by the introduction of the following natural enemies:

Natural enemies	Introduced: Origin	Introduced: Years
Hexamera signata (Walk.) (Tachinidae)	New Zealand	1931–5, 1937–9
Hexamera alcis (Walk.)	New Zealand	1931–5, 1937–9
Ichneumon suspiciosus Wesm.(Ichneumonidae)	England	1938–42
Bufo bufo (L.) (Bufonidae, Vertebrata)	England	1935

Hexamera signata and *H. alcis* parasitize *Porina* spp. (Hepialidae) in New Zealand, but were found to be capable of parasitizing *Oncopera* larvae. Small numbers of these parasites were liberated on each year of introduction from 1932 onwards, chiefly in Victoria but also in the Australian Capital

Territory. Neither species was recovered. The chief difficulty appeared to be that the grass grubs in Australia were not in a suitable stage to be attacked until late in the period when the fly is active in New Zealand.

It was found that the common European toad (*Bufo bufo*) would readily consume the larvae, pupae, and adults of *Oncopera*, but were unable to attack *Oncopera* in their burrows. The toads were not liberated. When the giant toad, *Bufo marinus* (Linn.), was introduced into Queensland in 1935 for the control of white-grubs (*q.v.*), it was hoped that it might also prove of use against *Oncopera mitocera* (Turn.), but these hopes were not fulfilled.

Ichneumon suspiciosus is a parasite of *Hepialus* spp. in England. It was at first erroneously identified as *Alomya debellator* (F.). It was imported on several occasions from 1938–42, but the consignments of parasitized hosts were generally unsuccessful, and *Ichneumon suspiciosus* was not liberated. No evidence was obtained that this species would parasitize larvae of *Oncopera*. Another parasite of *Hepialus* discovered in England was a polyembryonic hymenopteron. This unknown species was not sent to Australia.

Evans (168) has stated that no possibility exists of controlling *Oncopera* by natural enemies. So far as is known, most closely related species have a two-year, and not a one-year, life-cycle, and are root-feeders not grass-feeders. Many *Oncopera* are destroyed by native natural enemies, but its increase to very large numbers results from a succession of favourable weather and environmental factors.

Oncopera fasciculata (Walk.) has been studied in South Australia by Madge (357), who considers that natural enemies have very little influence on its numbers, except when wet weather forces larvae, prepupae, and pupae from their subterranean burrows. Birds were the most important predators, but no parasites were found.

Sources
37, 85, 86, 116 (1927–8, 1929–39, 1941–2), 168, 170, 241, 357, 512.

(37) **Potato moth**—*Gnorimoschema operculella* (Zell.) (Gelechiidae, Lep.)

Gnorimoschema operculella causes heavy losses throughout the potato-growing areas of Australia, being particularly important in Queensland, New South Wales, South Australia and Western Australia. It is also of some importance as a pest of tomato and tobacco. Some parasites of potato moth have been recorded in Australia but, although little is known about them, they appear to be comparatively unimportant.

In 1921, the Department of Agriculture of Western Australia imported *Bracon* (*Microbracon*) *gelechiae* Ashm. (*Habrobracon johannseni* Vier.) (Braconidae) from California, but the insects died in transit.

From 1943–8, C.S.I.R. and C.S.I.R.O. obtained from California many consignments of parasites of *G. operculella*, and several species were cultured and liberated. The species imported were:

Parasites	Introduced	Liberated
Bracon gelechiae	1943–6	1944–9
Chelonus phthorimaeae Gah.(Braconidae)	1943–6	1944–9
Macrocentrus ancylivorus	1944	
Agathis (*Microdus*) *gibbosus* (Say) (Braconidae)	1943–5	
Campoplex (*Omorgus*) *phthorimaeae* (Cushm.) (Ichneumonidae)	1943–8	1947–9
Copidosoma koehleri Blanch.(Encyrtidae)	1945–6	1946–9
Apanteles scutellaris Mues.	1948	

Of the four species released, all were liberated in Queensland, New South Wales, Australian Capital Territory and Victoria, but only *Bracon gelechiae* and *Chelonus phthorimaeae* were liberated in South Australia and Tasmania, and only *B. gelechiae* in Western Australia.

Chelonus phthorimaeae was recovered in the Australian Capital Territory (1944–5), and *Bracon gelechiae* in New South Wales (1944–5), but neither is known to be established. *Copidosoma koehleri* was recovered in the Australian Capital Territory and New South Wales (1945–7), and subsequent

collections in the field (1952–4) have shown this species to be established over a wide area of the potato-growing districts of Queensland and New South Wales, including many districts far from the liberation sites. Except in Queensland, the percentage parasitism by *C. koehleri* in most areas is still low.

The difficulties experienced in culturing *Macrocentrus ancylivorus*, *Agathis gibbosus* and *Apanteles scutellaris* prevented the liberation of these species.

The biological control of *Gnorimoschema operculella* in Australia has by no means been thoroughly explored. Field investigation since the parasites were released has been very restricted, and much work remains to be done on the introduction of parasites of this pest.

Sources
60, 97 (1948–54), 116 (1942–8), 317, 469 (1948–9), 501 (1949–50, 1952–3), 533 (1943–7), 542 (1920–2, 1944–5).

(38) **Sweet potato hawk moth**—*Hippotion celerio* (L.) (Sphingidae, Lep.)

Hippotion celerio was a serious pest of sweet potato and other plants in the Territory of New Guinea. The giant toad, *Bufo marinus*, was imported from Queensland and liberated at Keravat in 1936–7; it was distributed to various parts of the Territory by 1938–9. The toad became thoroughly established and reports in 1940 indicated that it was successful in controlling various insect pests including *Hippotion celerio*.

Sources
150, 196, 400, 502 (1936–7, 1938–9).

(39) **Cabbage centre-grub**—*Hellula undalis* (F.) (Pyraustidae, Lep.)

An unidentified braconid was introduced in 1907 from India into Western Australia for the control of cabbage centre-grub, but the parasite failed to become established.

Source
317.

(40) **Cutworms** (Noctuidae, Lep.)

A parasite of cutworms obtained in the Orient was imported into Western Australia in 1909 and liberated.

Source
412.

(41) **White grubs** (Scarabaeidae, Col.)

Several attempts have been made in Australia at the biological control of native white grubs, especially those infesting cane fields in Queensland, such as *Dermolepida albohirtum* (Waterh.), which is the most serious pest of sugar cane, and *Lepidiota frenchi* Blackb.

In 1894, the entomogenous fungus, *Botrytis tenella* Sacc.(*Isaria densa*), was imported from France by the Colonial Sugar Refining Co., and used in experiments in New South Wales and Queensland in the control of white grubs. Further work with this fungus was carried out in New South Wales in 1895, when negative results were obtained after spores of the fungus had been disseminated for the control of various white grubs (*Anoplognathus*, *Lepidiota*, etc.). About this time, cultures of *Botrytis tenella* were commercially available, and were extensively used against white grubs, though apparently to little effect. This fungus had been employed by Giard for the control of white grubs in France.

About 1914, the green muscardine fungus (Samoan fungus) *Metarrhizium anisopliae* (Metsch.) Sorokin, was introduced into Queensland from Samoa, although Tryon (520) pointed out that it already occurred in Queensland in association with *Dermolepida albohirtum*, the beetle it was intended

to control. *M. anisopliae* appeared to have considerable influence locally in controlling this cane beetle. Experiments in Queensland with the green muscardine fungus continued until about 1923. In experimental work, 50 per cent. of the grubs of *Lepidiota rothei* Blackb. were attacked by it. It also attacked *Lepidiota frenchi* and *Anoplognathus boisduvali* Boisd. In the field, it was observed to infest the greyback cane beetle, *Dermolepida albohirtum*, and *Rhabdoscelus obscurus*. At times considerable numbers of white grubs are destroyed by this fungus.

In general, fungi appear to be important natural enemies of white grubs in Queensland, especially where climatic conditions favour their propagation.

A bacterial epizootic caused widespread mortality to *Lepidiota caudata* Blackb. on the Atherton Tableland in 1937 (488).

In 1942–3, the Queensland Bureau of Sugar Experiment Stations made attempts to inoculate *Dermolepida albohirtum* with spores of the milky disease of Japanese beetle (*Bacillus popilliae* Dutky and *Bacillus lentimorbus* Dutky), but these attempts were unsuccessful.

A disease of *Sericesthis pruinosa* (Dalm.) (*Scitala pruinosa* Dalm.), caused by a bacterium considered to be a new variety of *Bacillus lentimorbus*, and named var. *australis* Beard, and a disease of *Heteronychus sanctae-helenae* Blanch. caused by *Bacillus euloomarahae* Beard, have recently been reported from Australia (67).

In 1926, *Triscolia rubiginosa* F.(Scoliidae) was brought to Queensland from Java by a sugar company for possible use against *Dermolepida albohirtum*. It was studied by the Bureau of Sugar Experiment Stations, but did not parasitize this insect, and was not liberated. It paralysed and oviposited on the larvae of *Dynastes* (*Xylotrupes*) *gideon* (L.) var. *australicus* (Thom.), but was not successfully reared on this host.

Parasites and predators of white grubs are reported to be abundant in Queensland, the digger wasps being probably the most efficient. Much attention has been given to the native species *Campsomeris tasmaniensis* Sauss. and *Dielis formosus* Guér.(Scoliidae).

The New South Wales Department of Agriculture introduced *Campsomeris marginella modesta* Sm.(*Scolia manilae* Ashm.) from Hawaii in 1926–7 and 1927–8 for the control of *Anodontonyx tetricus* Blackb. and *Sericesthis pruinosa*, but it did not parasitize these species. It was also introduced into Queensland for the control of cane grubs by the Bureau of Sugar Experiment Stations from Hawaii in 1919 (the material died *en route*) and from the Philippine Islands in 1931, but did not become established.

In 1931, *Campsomeris aureicollis* Lep. was imported from the Philippine Islands by the Bureau of Sugar Experiment Stations. It bred readily on *Dermolepida albohirtum*, *Lepidiota frenchi*, and *Lepidiota consobrina* Gir., and was bred for liberation primarily against *Dermolepida albohirtum*. Unfortunately, the culture dwindled and it was not liberated.

Another parasite imported by the Bureau of Sugar Experiment Stations was *Microphthalma michiganensis* Towns.(Tachinidae), brought in on two occasions (1931, 1932) from Canada for the control of *Pseudholophylla furfuracea* (Burm.), *Lepidiota trichosterna* Lea, and *Lepidiota frenchi*. This parasite in Canada attacks related species but was not bred on the Australian species in the laboratory. It was liberated in North Queensland in 1932 and 1933, but was not recovered.

The giant toad, *Bufo marinus*, was introduced into Queensland from Hawaii by the Bureau of Sugar Experiment Stations in 1935, for the control of *Dermolepida albohirtum* and other coleopterous cane pests. It was also hoped that it might become established on the Atherton Tableland, and reduce the populations of such white grubs and grass grubs as *Lepidiota caudata*, *Lepidiota laevis* Arrow, and *Oncopera mitocera*.

Bufo marinus was liberated in 1935–6, and was rapidly established in all the sugar-cane areas of the State. It is now present in all coastal districts, and is generally abundant. The toads prey on insects of many families, including numerous scarabaeids; *Dermolepida albohirtum*, *Lepidiota frenchi*, *Rhabdoscelus obscurus*, and army worms are among the species taken. The absence of cover during the day is, in some areas, possibly an important limiting factor. *Rhabdoscelus obscurus*, which thrives in the wetter districts where the toad is more numerous, is commonly preyed on, and according to

one report the toad has contributed to its control. *Bufo marinus* consumes large numbers of insects of economic importance, but evidence is lacking as to whether it has significantly reduced the abundance of the greyback cane beetle or any other pest species.

Sources
5, 67, 154, 204, 282, 284, 285, 286, 288, 289, 290, 292, 297, 301, 302, 328, 390, 391, 392, 393, 394, 402 (1895, 1925–8), 452, 468 (1923–4, 1930–1, 1934–44), 487, 488, 516, 520, 525, 527.

(42) **Cane weevil borer**—*Rhabdoscelus obscurus* (Boisd.) (Curculionidae, Col.)

Rhabdoscelus obscurus entered North Queensland from New Guinea about 1893, and became a sugar-cane pest second in importance only to white grubs (*Lepidoderma*, *Lepidiota*, etc.). New Guinea and the adjoining islands are thought to be the original habitat, and sago, other palms, and banana the original host-plants.

Ceromasia sphenophori Vill.(Tachinidae) is parasitic on *Rhabdoscelus obscurus* in Amboina, Ceram and Papua. It was introduced into Queensland from Papua in 1896 and 1910, and from Fiji in 1914. It was found to be established and plentiful in the Mosman area in 1918, and in the following years until about 1931 it was distributed to other sugar-cane areas by the Queensland Bureau of Sugar Experiment Stations. High percentage parasitism has been recorded, but the parasite probably cannot maintain itself outside the Mosman-Tully area. It has been reported that *Ceromasia sphenophori* exercises a high degree of control over the host where climatic and other conditions are favourable. According to Smith (490), on the other hand, the introduction of *C. sphenophori* produced little or no change in the position. *Rhabdoscelus obscurus* has been extremely rare since pre-harvest burning of cane became standard practice in Queensland. The burning of the cane is an important check on the parasite.

The green muscardine fungus, *Metarrhizium anisopliae*, attacks the cane weevil borer in Queensland, and the possibility of using this fungus to control the borer was under consideration in 1923–4.

In 1928, cultures of an entomogenous fungus, which attacks a related pest on sugar cane in the Philippine Islands, were brought to Queensland for possible use against *Rhabdoscelus obscurus*. It was cultured on different media, and transmitted to *R. obscurus*.

Plaesius javanus is predatory on *R. obscurus* in the East Indies, and this predator was introduced into Australia for the control of the banana weevil borer (*q.v.*), but was not established.

Bufo marinus, the giant toad introduced against white grubs (*q.v.*), commonly preys on the cane weevil borer and, according to one report, has contributed to the control of this insect. However, the main reduction in the cane weevil borer population has apparently resulted from the practice of burning the cane before harvesting.

Sources
279, 280, 281, 283, 291, 292, 293, 294, 295, 296, 298, 299, 300, 389, 390, 468 (1923–31, 1934–6, 1943–4, 1946–7, 1949–50), 469 (1909–10, 1914–5), 490, 500, 525, 527.

(43) **Vegetable weevil**—*Listroderes obliquus* Klug (Curculionidae, Col.)

Listroderes obliquus, which is of South American origin, occurs in all the States of Australia. It is widely distributed and is found on a wide range of vegetables and weeds. Its importance as a pest seems to vary greatly in space and time. Although it is not a consistently serious pest, it causes serious damage intermittently to crops or various vegetables and occasionally flowers.

In 1957, C.S.I.R.O. introduced parasites of *Listroderes* obtained in Argentina and Uruguay. These parasites included *Stomatomyia* (*Epiplagiops*) *littoralis* Blanch.(Tachinidae), which was liberated in the Australian Capital Territory in 1957, and three or four species of *Tersilochus* (*Porizon*) (Ichneumonidae), including *T. parkeri* (Blanch.), *T.* sp.? *argentinensis* (Blanch.), and one or two apparently undescribed species.

Source
97 (1955–7).

(44) **Pea weevil**—*Bruchus pisorum* (L.) (Bruchidae, Col.)

Bruchus pisorum is an important pest of peas in Western Australia, where it first appeared in 1931. This exotic species has not yet been recorded from other parts of Australia.

In 1939, C.S.I.R. imported the parasite *Triaspis thoracicus* Curt.(Braconidae) from France, and liberations were made in Western Australia. The parasite reproduced in the field and was recovered, but did not survive the winter of 1940. A subsequent attempt by the Department of Agriculture in 1942 to import this species from the U.S.A. was unsuccessful.

The failure to establish *Triaspis thoracicus* possibly resulted from the absence in Western Australia of an alternative host in which the parasite can pass the months in which suitable stages of *Bruchus pisorum* are not present in the field.

Sources
116 (1938–41), 317, 542 (1939–40, 1941–3).

(45) **Garden snail**—*Helix aspersa* Mull. (Helicidae, Mollusca)

C.S.I.R. introduced a snail predator, *Lampyris noctiluca* L.(Cantharidae), from England in 1935 for the control of *Helix aspersa* and allied species. Three small liberations of larvae were made in the Australian Capital Territory in 1936 and 1937. Some adults were recovered later, but the insect did not become established.

Source
116 (1935–9).

(46) **Giant African snail**—*Achatina fulica hamillei* Bow. (Achatinidae, Mollusca)

During their occupation of parts of New Guinea during the last war, the Japanese introduced the giant African snail as a source of food. The main centres of infestation are now Kavieng District in New Ireland, Rabaul District in New Britain, and Madang and Hansa Bay on the mainland. This snail is probably more of a horticultural than agricultural pest, and causes much damage in food and flower gardens.

The Department of Agriculture, Stock, and Fisheries is attempting to control the snail by the introduction of predators. The predatory snail *Gonaxis quadrilateralis* (Preston) (Streptaxidae) was imported from Kenya in 1957, and several liberations were made in this year in the Gazelle Peninsula of New Britain. This predator is being bred for general liberation. Another predatory snail, *Euglandina rosea* (Férr.) (Oleacinidae), was introduced unsuccessfully from Florida in 1956. It was re-introduced from Hawaii in 1957. Plans for the introduction of another snail predator, *Tefflus hacquardii* Chaud. (Carabidae), have not yet been fruitful. It is intended to import other predators, particularly *Streptaxis kibweiziensis* Smith.(some authorities regard *G. quadrilateralis* as a synonym of *S. kibweiziensis*.)

Sources
151, 152, 153, 502 (1946–9, 1952–3, 1955–7).

C. SILVICULTURAL PESTS

(47) **Araucaria mealy bug**—*Eriococcus araucariae* Mask. (Dactylopiidae, Hem.)

When *Cryptolaemus montrouzieri* was established in 1902 in Western Australia, having been introduced from New South Wales for the control of mealy bugs (*q.v.*), it also proved effective in controlling *Eriococcus araucariae* on Norfolk Island pine (*Araucaria excelsa*) in Perth.

Source
18.

(48) **Pine aphid**—*Chermes boerneri* (Ann.) (Adelgidae, Hem.)

This American species is of some importance in all Australian States as a pest of Monterey pine (*Pinus radiata*) and many other species of *Pinus*. It is especially troublesome on young plantation and nursery trees.

The pine aphid was erroneously identified as *Chermes pini* Koch, and an investigation was carried out by C.S.I.R. into the natural enemies of *C. pini*, *C. strobi* Hartig, and related species in England. This led to the consignment to Australia from England, during the period 1932–40, of many species predatory on *Chermes*. No parasites were discovered. When the correct identification of the pine aphid became known, a brief survey of its natural enemies in California was made, and a small consignment of *Leucopis atrifacies* (Ald.) (Ochthiphilidae) was imported.

The following table lists the species imported and liberated:

Predators	Introduced		Liberated
	Origin	Years	
Leucopis obscura Hal.	England	1932–6, 1938	1932–6, 1938–9
Leucopis atrifacies	California	1938	1938
Lipoleucopis praecox de Meij.(Ochthiphilidae)	England	1932–3	1933
Lestodiplosis pini Barnes(Cecidomyiidae)	England	1933	
Hemerobius stigma Steph.(Hemerobiidae)	England	1932, 1934–6, 1939–40	
Hemerobius nitidulus Fab.	England	1935–6, 1939–40	
Wesmaelius concinnus Steph.(Hemerobiidae)	England	1935–6, 1939	1936–7
Exochomus quadripustulatus (L.) Coccinellidae)	England	1933–8	1934–5, 1937–9
Anatis ocellata (L.) (Coccinellidae)	England	1933, 1935	
Adalia bipunctata (L.) (Coccinellidae)	England	1935–6	
Scymnus suturalis Thunb.	England	1936	

Only five of the eleven species imported were liberated, the liberations being made in the Australian Capital Territory and New South Wales. Although on two occasions *Leucopis obscura* was recovered in the field, none of the species liberated is thought to be established.

The attempt to establish predators of *Chermes* was adversely affected by mortality in shipment from England, the failure of the imported adults of some species to develop to sexual maturity, the inability to rear or breed other species in the insectary prior to liberation, and the difficulty involved in adjusting the life-cycle to the change of seasons resulting from the transfer to the southern hemisphere. There was hesitation also in liberating some of the neuropterous and coccinellid predators, which were known or suspected to be predatory on *Leucopis obscura*. In addition, there may have been basic difficulties associated with the initial error in the identification of the pest, in the climatic unsuitability of the environment, or the unsuitability of the time of liberation of the rather small numbers of insects released.

Some native coccinellids and a chrysopid are predatory on *Chermes boerneri* in Australia, and one of these, *Diomus pumilio* Ws.(Coccinellidae), appears to be of considerable value in controlling it in the Australian Capital Territory and also in Queensland, where specimens sent from Canberra were liberated in 1936 and 1937. Though at the time, it appeared that *D. pumilio* did not occur in Queensland, it now seems likely that the species was already present there.

Sources
116 (1931–9), 546.

(49) **Oak aphid**—*Myzocallis annulata* (Hart.) (Aphididae, Hem.)

The oak aphid is a common insect on oaks (*Quercus*) in the Australian Capital Territory and New South Wales, and has been responsible for considerable damage to oak trees in Victoria and Tasmania. Investigations were carried out by C.S.I.R. in England, where this species is native, and four parasites were consigned to Australia:

Parasites	Introduction	Liberation
Praon volucre (Hal.) (Braconidae)	1936–8	
Praon flavinode (Hal.)	1936–8	
Tryoxis cirsii (Curt.) (*aceris* (Hal.)) (Braconidae)	1936–8	
Aphelinus flavus (Nees)	1937–8	1939

Little of the material sent provided adult parasites and the only species successfully bred in the insectary was *Aphelinus flavus*. Before liberations were made, this parasite was discovered in the field

in the Australian Capital Territory (where it was considered to have appeared very recently by accident) and also at Hobart, Tasmania. However, specimens of *Aphelinus flavus* provided by C.S.I.R. were liberated at Launceston, Tasmania. *Tryoxis cirsii* was found in 1939 to be already established and widespread at Hobart, together with *Asaphes vulgaris* Walk.(Pteromalidae), a hyperparasite of *T. cirsii*.

Further introductions of parasites were not made, but the Department of Agriculture distributed the two established parasites in Tasmania during 1939–41. As a result of the natural and artificial spread of the parasites, the aphid became heavily parasitized by one or other of the two parasites in many areas in Tasmania, and the health of the oaks in such areas has gradually improved. No assessment of the efficacy of the parasites has been made in other States.

Sources
116, 1936–9), 164, 170, 378.

(50) **Golden oak scale**—*Asterolecanium variolosum* (Ratz.) (Asterolecaniidae, Hem.)

This European scale is of some importance as a pest of oak trees (*Quercus*) in Tasmania, Victoria, New South Wales and South Australia. In Tasmania it is widespread and oaks were severely affected.

The parasite *Habrolepis dalmani* (Westw.) (Encyrtidae) was introduced by C.S.I.R. from New Zealand, where it had earlier been established from specimens obtained from U.S.A. Consignments arrived from New Zealand in 1931 and 1932, and liberations were made in Tasmania. Recoveries were not made, and the parasite was imported and released again in 1933. From this introduction it became quickly established, and was distributed widely in Tasmania by the Department of Agriculture.

In 1937, *Asterolecanium variolosum* appeared in heavy infestations on ornamental *Quercus robur* in the Australian Capital Territory, and *Habrolepis dalmani* was obtained (from Tasmania and New Zealand) and released there. It established rapidly, and in 1938 consignments were sent to New South Wales and Victoria, where liberations were also made. An unidentified chalcidoid hyperparasite was found in the material received from Launceston.

Habrolepsis dalmani has provided a useful measure of control of the scale in Tasmania, where there has been an improvement in the health of the oak trees. The value of the parasite elsewhere has not been assessed.

Sources
116 (1933–9), 164, 170, 242, 378, 426.

D. MISCELLANEOUS PESTS

(51) **Angoumois grain moth**—*Sitotroga cerealella* (Ol.) (Gelechiidae, Lep.)

Two ichneumonid parasites of *Sitotroga cerealella* were obtained at Valencia, Spain, in 1903. These were sent to Western Australia where some were released. According to one report (16) this consignment possibly included some parasites of the grain weevil.

Sources
16, 99, 133, 137.

(52) **Australian sheep blowfly**—*Lucilia cuprina* (Wied.) (Calliphoridae, Dipt.)

Lucilia cuprina is responsible for most blowfly strike of sheep in Australia. Other species involved in sheep strike are *Calliphora augur* (F.) and *C. stygia* (F.) in eastern Australia and *C. nociva* Hardy and *C. australis* (Boisd.) in Western Australia. Of the secondary flies, *Chrysomyia rufifacies* (Macq.) and *Chrysomyia micropogon* Bigot are the most important.

The first attempt in Australia at the biological control of sheep blowflies was the introduction in 1911 of a sarcophagid parasite of Japanese origin from Hawaii by the Western Australian Department of Agriculture. This parasite, which was also intended for use against *Musca domestica* L. (Muscidae), was not established.

In 1913, the cosmopolitan pupal parasite, *Nasonia vitripennis* (Walk.) (*Mormoniella vitripennis* Walk.; *Nasonia brevicornis* Ashm.) (Pteromalidae), was found in both New South Wales and Queensland. It was cultured from 1914 onwards for some years, and millions were liberated widely in New South Wales and Queensland. This parasite can parasitize only exposed puparia, and it has been estimated that at most only 4 per cent. of blowfly puparia are available for its attack. *Nasonia vitripennis* was sent from New South Wales to all States. It was established in Western Australia in 1915, and was distributed in that State until 1925. Though generally established, it nowhere has any evident effect on blowfly populations.

In eastern Australia, the following species also are parasites of blowflies:

Brachymeria rubriventris (Gir.) (*Chalcis calliphorae* Frogg.) (Chalcididae)
Dirhinus ruficornis (Gir.) (*sarcophagae* Frogg.) (Chalcididae)
Tachinaephagus zealandicus Ashm.(*Australencyrtus girault* Johns. and Tiegs, *Stenosterys fulvoventralis* Dodd) (Encyrtidae)
Hemilexomyia abrupta Dodd (Diapriidae)
Brachymeria dipterophaga (Gir. and Dodd)
Paraspilomicrus froggatti Johns. and Tiegs(Diapriidae)
Spalangia muscidarum Richar.(Pteromalidae)

One of these species, *Tachinaephagus zealandicus* was found in Western Australia, where it was reared and distributed for several years about 1928–31, but has not proved to be of any value in blowfly control.

The larval parasite, *Alysia manducator* Panz.(Braconidae), has been introduced into Australia on several occasions:

	Introduced		
Imported by	Origin	Year	Liberated
New South Wales Department of Agriculture	England	1925–8	1928, 1929
C.S.I.R.	New Zealand	1928, 1929	
Western Australian Department of Agriculture	England	1927	
	New Zealand	1929	

The Western Australian Department of Agriculture also obtained supplies of *Alysia manducator* from New South Wales in 1928–9, and from C.S.I.R. in 1930.

This parasite was reared on the smooth-bodied maggots of *Lucilia* and *Calliphora*, but not on the hairy maggots of *Chrysomyia*. Liberations of *Alysia manducator* in New South Wales did not result in its establishment. Adverse influences in the Australian environment were the dryness of the soil in summer, the loss of vigour of the parasite adults in hot weather, the attacks of *Nasonia vitripennis* on puparia already parasitized by *Alysia*, the scarcity of smooth-bodied maggots during the summer, and the attacks of carrion beetles and ants.

C.S.I.R. carried out investigations on *Alysia manducator* in Australia and France, but did not liberate this parasite for the following reasons:

(1) *Alysia* prefers carrion in the shade to carrion in the sun, and the great majority of carcasses in Australia would not be affected by it.

(2) *Alysia* works best in moist weather and in autumn, and the dry conditions operating in most of the sheep country of Australia would greatly restrict its activities.

(3) In France, *Alysia* is not an important factor in limiting the abundance of blowflies, though the general conditions are more favourable for the parasite than they would be in Australia.

In general, it is considered that the biological control of sheep blowfly is almost an impossibility. The blowfly population is limited primarily by intense competition for the available larval food supply. The total effect of all the natural enemies, whether parasites or predators, is merely to reduce the intensity of this competition. There remains a remote possibility that a natural enemy which attacked the later stages of the blowflies, and operated after competition had played its part, might reduce adult fly density below that determined by competition for food alone. To this end, C.S.I.R. introduced from France in 1930 *Saprinus semistriatus* Scriba (*nitidulus* F.) (Histeridae). However, a

culture of this predator could not be established, and the insect was not released. Another possibility would be to introduce some carrion-feeding animal, harmless in itself, which would be an efficient food competitor for *Lucilia*. So far no species adequate for the purpose is known. It appears improbable that further attempts at the biological control of sheep blowfly will be made.

Nicholson has employed *Lucilia cuprina* in laboratory experiments which have been concerned with the population effects of competition for food, and with the general problems of the dynamics of animal populations. Nicholson's papers dealing with these experiments are included in the sources below.

Sources

33, 48, 116 (1928–31), 185, 216, 217, 218, 223, 227, 229, 230, 248, 261, 262, 263, 270, 271, 272, 317, 322, 324, 329, 331, 332, 334, 356, 375, 386, 398, 402 (1914–8, 1920–30), 417, 418, 421, 423, 428, 432, 434, 435, 436, 437, 438, 504, 542 (1910–2, 1913–4, 1918–32).

(53) **Buffalo fly**—*Siphona exigua* (de Meij.) (Muscidae, Dipt.)

The buffalo fly is thought to have been introduced into Australia when the first herds of buffalo were landed at Darwin about 1826. Since that time it has assumed considerable importance, spreading through the north of Australia from Western Australia to Queensland.

Preliminary investigations into the natural enemies of *Siphona exigua* were carried out in 1927 by Otto Nieschultz of the Veterinary Institute, Buitenzorg, at the request of C.S.I.R. Buffalo fly is not a pest of any importance in most parts of Indonesia. A C.S.I.R. survey in 1929, extended the knowledge of the parasites of buffalo fly in this area. Handschin in 1931 investigated further the most promising species, *Spalangia sundaica* Grah., which parasitizes the puparia. This parasite was introduced into northern Australia in 1932. It interbred readily with a native parasite, *Spalangia orientalis* Grah., which was already parasitizing *Siphona exigua* in the field. Both these species and a hybrid of them were liberated in the Northern Territory and Western Australia in 1932 and 1933. These releases had no evident effect on the abundance of buffalo fly. *Spalangia sundaica* either failed to become established or merged by interbreeding with *S. orientalis*. The level of parasitism of the puparia by *Spalangia* remained at a low level.

Further investigations in Java led to the conclusion that the low density of *Siphona exigua* in that country was primarily a result of dung being rendered unfavourable for the larvae by high rainfall (340).

Several attempts have been made to establish predators of dung-feeding muscoid larvae in Australia. *Hydrotaea dentipes* F.(Muscidae), the larvae of which are predatory on other dipterous larvae in dung, was introduced by C.S.I.R. from England in 1928, but the predator could not be bred in captivity, and it was not released. Another species of this genus, *H. australis* Mall., which is commonly associated with *Siphona exigua* in dung in Australia, undoubtedly helps to reduce the abundance of buffalo flies, and the presence of this well adapted and widely distributed native species of *Hydrotaea* casts doubt on the value of liberating another species of the genus.

Investigations in Haiti (399) indicated that dung-competitors and parasites were unimportant in the control of the horn-fly, but several predators of horn-fly larvae were present, including *Hister coenosus* Er.(Histeridae). Subsequently, two histerid predators were introduced by C.S.I.R. *Hister coenosus* was imported from Haiti in 1939, but the specimens died *en route*. In 1944–5 and in 1946, *Pachylister chinensis* was imported from Fiji and liberated near Cairns, Queensland. Both adults and larvae of this predator attack the maggots of *Siphona exigua*. It is not known if *Pachylister chinensis* is established.

A number of staphilinids, silphids, and histerid predators of the immature stages of *Siphona exigua* occur in Australia.

Sources

34, 87, 116 (1928–46), 231, 260, 317, 340, 351, 355, 399, 474, 508.

(54) **Mosquitoes** (Culicidae, Dipt.)

On reviewing the literature concerning the biological control of mosquitoes in Australia and Australian New Guinea, important gaps in the published record became evident. These gaps were

partly filled by correspondence with many authorities in Australia, and information so obtained has been incorporated in this review.

The reasons for interest in the possibility of controlling mosquitoes by fish predators differed in different parts of the Australia-New Guinea area. In most Australian States, the nuisance of mosquito biting was the principal concern. In Queensland, the presence of filariasis and malaria were additional important reasons, whilst in New Guinea, the prevalence of malaria was the main consideration. Dengue fever, of which *Aëdes aegypti* L. is the most important vector, also occurs in New Guinea and northern Australia. Perkins (460) has reviewed the mosquito problem in Queensland and in Australia generally, and has discussed the species involved and their breeding habitats.

Apparently the first published proposals in Australia for the use of fish to control mosquitoes were those of Stead (494) in 1907, who suggested that native *Galaxias* spp. be introduced into ponds and tanks for this purpose, and Bancroft (66) in 1908, who suggested the use of *Eleotris*, gobies, or gold carp. That fish could be useful predators of mosquitoes had been shown by the introduction in 1905 of the mosquitofish, *Gambusia affinis* (Baird and Gir.) (Poeciliidae), into Hawaii from Texas.

The fishes which have attracted the interest of those concerned with the control of mosquitoes in Australia and Australian New Guinea are as follows:

EXOTIC SPECIES

Gambusia affinis—mosquitofish
Lebistes reticulatus (Pet.) (Poeciliidae)—guppy
Heterandria formosa Agas.(Poeciliidae)—dwarf top minnow
Tilapia mossambica Pet.(Cichlidae)—Mozambique mouthbreeder
Perca fluviatilis Linn.(Percidae)—English perch
Macropodus opercularis (Linn.) (Anabantidae)—paradisefish
Carassius auratus (Linn.) (Cyprinidae)—goldfish

NATIVE SPECIES

Carassiops galii Ogil.(Eleotridae)—firetail
Melanotaenia nigrans Rich.(Atherinidae)—crimson-spotted sunfish
Pseudomugil signifer Kner(Atherinidae)—blue-eye
Priopis olivaceus Ogil.(Centropomidae)—green perchlet
Galaxias attenuatus (Jen.) (Galaxiidae)—jolly-tail
Craterocephalus fluviatilis McCull.(Atherinidae)—freshwater silverside
Retropinna semoni Web.(Retropinnidae)—Australian smelt
Chanda spp.(*Ambassis*) (Centropomidae)—chanda perches

Of the exotic species, the mosquitofish, *Gambusia affinis*, has proved of greatest significance in mosquito control. It has been present in Australia as an aquarium fish for more than forty years, but in 1926 the Chief Health Inspector of the City of Sydney, New South Wales, established the species from specimens imported from Italy (C. F. Fegan, personal communication). Fish from this source were distributed in New South Wales, Queensland, and probably some other mainland States, and in the Territory of Papua and New Guinea.

In New South Wales, liberations were made in many country towns from 1927 until the last war, when *Gambusia* was widely established in the State. City and Municipal Councils distributed the fish in the Newcastle and northern coastal region until about 1930.

In Queensland, *Gambusia* was liberated in creeks and streams in the Brisbane area for some years from 1925 by Hamlyn-Harris, Entomologist of the Brisbane City Council, who obtained specimens from a Sydney aquarist. *Gambusia* was also sent to Brisbane in 1929 by the Chief Health Inspector, Sydney. Another source of *Gambusia* liberated in Queensland was a quarry at Wynnam, near Brisbane, where water had been stocked with fish from northern New South Wales rivers. The mosquitofish became well established in southern Queensland, and during the war was found as far north as Cairns.

Gambusia was first imported into the Territory of New Guinea in 1930. Fish from Sydney were established at Rabaul, and between 1930 and 1940 were distributed to all parts of the Territory, and widely established. From Rabaul, specimens were sent to Papua (Port Moresby and Samarai),

the first introduction being made in 1933. During the next few years the fish were widely established in Papua.

Gambusia is believed to have been first liberated in South Australia in the Finnis River in the early nineteen-thirties. It is now widely distributed in the Murray and Finnis Rivers, and in several smaller streams around Adelaide (A. R. Southwood, personal communication).

In Western Australia, the first liberation was made in 1934, when an amateur pisciculturist released specimens in irrigation trenches at Nedlands (D. J. R. Snow, personal communication). Mosquitofish were later placed in swamps around Perth, and in 1940 were sent to Broome. They are now common in Western Australia.

Gambusia was sent to Darwin in the Northern Territory in 1940. It is said to be present in Melbourne, Victoria, but has not been introduced into Tasmania.

The distribution of *Gambusia* was undertaken during the last war by Malarial Control Units of the Australian and United States armies. The fish were bred in hatcheries at Enoggera, Chermside, Port Moresby and elsewhere, and were collected from natural infestations, as in the creeks and backwaters of the Tweed River and the Waigani swamps, near Port Moresby. From such sources, vast numbers were distributed in creeks, swamps, bomb holes, tanks, drains, etc. in Papua and New Guinea, and in waters around camps in Queensland, New South Wales, and possibly Victoria and other mainland States.

The general opinion of those concerned with mosquito control in Australia and Australian New Guinea is that the introduction of *Gambusia* has reduced mosquito abundance.

A. R. Woodhill (personal communication) comments that under suitable conditions *Gambusia* maintains excellent control, due to its reproductive powers and extreme hardiness.

D. J. Lee (personal communication) states that *Gambusia* is widely distributed along the eastern coastline of Australia and exerts good control of mosquitoes in permanent pond habitats. Elsewhere, it can be useful but must be used deliberately to be effective. It is usually successful only in permanent bodies of water, but even these can be flushed out by floods along the eastern rivers with the necessity of replenishment from a stock source.

However, H. G. Wallace (personal communication) considers that the use of *Carassiops galii* (see below) and *Gambusia* in Newcastle and the north coast of New South Wales was unsuccessful.

In Queensland, Hamlyn-Harris was convinced of the efficacy of *Gambusia*, recommending its use in the Brisbane area, and the restocking of ornamental waters in spring-time. He expected that *Gambusia* would thrive in northern Queensland (258). J. D. Mabbett (personal communication) has expressed the opinion that, in the absence of *Gambusia*, mosquitoes would immediately and generally become an intolerable nuisance in Brisbane.

In Western Australia, according to D. J. R. Snow (personal communication), *Gambusia* controlled mosquitoes in Nedlands irrigation ditches, and the fish were successful in the suppression of local mosquito breeding in swamps around Perth.

In South Australia, according to the Curator of Fishes at the South Australian Museum (A. R. Southwood, personal communication), *Gambusia* has been moderately successful: it has been helpful in controlling the mosquito hazard in the Murray and Finnis Rivers, and several smaller streams in the vicinity of Adelaide.

Brennan (76) in 1935 considered the introduction of *Gambusia* to be the most successful anti-malarial measure undertaken in New Guinea. At Rabaul, the fish were reported to have completely eradicated mosquito larvae from a crater lake south of the town, and by 1940, the township had become free of anopheline mosquitoes (502). The fish were found to be suitable for open tanks, the upper reaches of rivers, inland streams, dredge pits, and permanent swamps. The use of *Gambusia* was combined with other measures, such as drainage, encouragement of shade, and oiling. Similar measures were applied in other towns in the Territory, but the low human population did not allow mosquito breeding to be kept at a level low enough to prevent transmission of malaria. According to G. S. Dun (personal communication), *Gambusia* was quite ineffective in the Gazelle Peninsula of New Britain, where the soil is of such low water-retaining capacity that the small streams in which the mosquitofish flourish dry up entirely after two or three weeks without rain.

Malaria had always been severe in the islands of Aua and Maty. *Gambusia* was established at Aua in 1934 and was distributed throughout the island. In a year, the spleen rate fell to 4 per cent., while in Maty (where the fish had not been liberated) it remained high at 63 per cent. (76).

Malaria is endemic in New Ireland, and in 1930 the town of Kavieng was badly infested with *Anopheles* and other mosquitoes breeding in drains and ponds. Measures of control proved ineffectual until mosquitofish were introduced, when the town was quickly freed of mosquitoes. *Gambusia* was introduced into all known breeding places of *Anopheles* over a coastal area of seventy-two miles in 1931 and, in the thirty-two villages treated, successive spleen rates recorded over a period of nearly two years were 24·6, 16·8, 12·8, and 4·2. The corresponding figures for the remainder of the subdivision, where *Gambusia* was not liberated, were 47·1, 23·9, 24·7, and 28·8 (273).

In the town area of Port Moresby (Papua), *Gambusia* maintained underground tanks and large aboveground tanks free of mosquito larvae, but they were not effective in smaller, one thousand gallon, tanks. Mosquitofish placed in all freshwater springs around Port Moresby kept them free of *Anopheles* larvae. They were also effective in a number of lagoons. *Gambusia* appeared to be an important factor in mosquito control throughout the Territory of Papua (503).

During the war, control measures in New Guinea and Papua included larval control by draining, filling and flushing, oiling and spraying, as well as many measures against adult mosquitoes. In a complex programme *Gambusia* played a significant part (70). Ford (177) writes of the Australasian region that, during the war, *Gambusia* provided a measure of success in places where more expensive methods were impractical. Mosquitofish were distributed widely as an ancillary measure by Army units. The fish were of value in isolated breeding places which were difficult of approach by control gangs, such as bomb craters in the midst of jungle, but the fish were distributed, as a routine measure, in all suitable waters in the vicinity of bases. Where the edges of water could be kept free of weeds, complete control was established, although frequently, from inability to do so, breeding was reduced rather than abolished.

Despite the great development in insecticidal methods of combatting mosquitoes, the distribution of mosquitofish has continued in the post-war period in New Guinea, where they have been introduced into the Western Highlands. They have also been distributed wherever possible in Papua, where they are considered to be important in helping to break the malaria cycle (503).

The establishment of *Gambusia* in Australia has been strongly criticized. *Gambusia* is regarded as a pest by fisheries authorities in both Queensland and New South Wales because it is predatory on the fry of other fishes. Its distribution in northern New South Wales was discouraged because of the fear that it might spread to streams used by anglers (H. G. Wallace, personal communication), and its distribution in Queensland is now prohibited by a law administered by the Department of Harbours and Marine (T. O'Shea, personal communication).

Whitley (544) has expressed what is probably the general view of fisheries authorities: it is unwise to liberate foreign or even Australian fishes indiscriminately in Australian waters, and biological and hydrographical surveys should precede any introductions, which should be approved by fisheries authorities. Whitley considers *Gambusia* to be a general pest, competing very successfully with native fishes for food and attacking the fry of some species. While acknowledging that fish predators have proved valuable in some malaria and yellow fever ridden countries, Whitley considers the introduction of *Gambusia* into Australia, which is almost malaria-free, to have been unwarranted, for native fishes are almost as expert in destroying mosquitoes and do not upset the economy of the waters they frequent.

Comparatively little attention has been given to other exotic fish predators of mosquitoes.

Macropodus opercularis, together with several Australian fishes (see below), was introduced into New Guinea in 1914, with the intention of breeding them at Rabaul and distributing them throughout the Bismarck Archipelago for mosquito control (73). This Asiatic species is known to occur wild in New South Wales (544).

Lebistes reticulatus has long been present in Australia as an aquarium fish, but apparently is not established in Australian waters. In Queensland, Cooling (109–10) found that *Lebistes* was able to

maintain ponds free from mosquito larvae, and could adapt itself to large or small bodies of water. However, he opposed its introduction into Queensland waters (see below).

Hamlyn-Harris (258) records that *Lebistes* was very successfully employed against mosquitoes around Brisbane. The fish safely overwintered in copious weed growth, and Hamlyn-Harris suggested that such places as evaporation tanks should be restocked each spring.

Borthwick (74) attempted to establish *Lebistes* in Adelaide, South Australia, but the fish did not survive the winter. This species also failed to survive frosts when introduced into Sydney from Colombo in 1926 by the Chief Health Officer (C. F. Fegan, personal communication).

The use of *Carassius auratus* for the control of mosquitoes in ponds was proposed by Bancroft in 1908 (66), and *Perca fluviatilis* has been introduced into dams in South Australia to control mosquitoes as well as to provide food and sport (H. M. Hale, personal communication). Both these species are regarded as pests in some Australian rivers, having spread considerably at the expense of native fishes (544).

According to a press report, *Heterandria formosa* was found unsuitable for controlling mosquitoes in Sydney, New South Wales, in 1925 (G. P. Whitley, personal communication).

In 1954, *Tilapia mossambica* was introduced from Singapore into Papua and New Guinea as a source of protein food. The fish was established at Port Moresby and Goroka. The introduction has been criticized on the grounds that the establishment of fish ponds would increase the risk of malaria. These fish live mainly on plant food, but are also predatory on mosquito larvae. Experience so far shows that there is a great decline in mosquitoes when *Tilapia* become sufficiently established to remove the surface vegetation (A. M. Rapson, personal communication). It is believed that *Tilapia*, which appears to do very well in ponds and swamps, will assist in controlling mosquito larvae (502).

That native fishes are useful in the control of mosquitoes in Australia was the opinion of Cooling and other workers (90, 109–14, 258, 455, 544), some of whom opposed the introduction of exotic species on the grounds that native fishes were efficient mosquito predators and better adapted to Australian waters. However, it was recognized in Queensland that, though some fishes were effective enemies of mosquitoes in clean waters, none was effective in the sewage-polluted waters in which *Culex fatigans* Wied., the chief vector of filariasis, preferably breeds. Also, Cilento (91) considered that little had been done to determine which Australian fishes were as useful as *Gambusia*.

Of the Australian species which have been considered to be useful for mosquito control, *Melanotaenia nigrans* is widely distributed in eastern Australia and New Guinea, *Craterocephalus fluviatilis* and *Carassiops galii* are Queensland species, *Priopis olivaceus*, *Pseudomugil signifer* and *Retropinna semoni* occur in both Queensland and New South Wales, and *Galaxias attenuatus* is found in New South Wales. *Craterocephalus fluviatilis* is present in the Murray river system. *Melanotaenia nigrans*, *Craterocephalus fluviatilis*, *Carassiops galii* and *Priopis olivaceus* are fresh water species: *Pseudomugil signifer* and *Galaxias attenuatus* inhabit both fresh and salt water.

In 1914, the German Government of New Guinea after two failures, successfully imported from Australia *Galaxias attenuatus*, *Carassiops galii*, *Pseudomugil signifer*, and the exotic *Macropodus opercularis*, with the intention of breeding them at Rabaul and distributing them throughout the Bismarck Archipelago (73).

In South Australia, the establishment of a fish hatchery at Adelaide was planned in 1923 as part of an anti-mosquito campaign. The breeding and distribution of fish predators of mosquitoes was proposed, and *Melanotaenia nigrans*, *Priopis olivaceus* and *Carassiops galii* were species considered for use. A by-law passed in 1922 compelled landowners to deal with mosquito-infested waters by one of several methods which included the use of fish predators (74).

In the period about 1925–30, *Melanotaenia nigrans* was liberated to control mosquitoes in polluted storm-water drains in the Newcastle area of New South Wales, but it did not prove effective, possibly because of the weed-choked condition of the drains (H. G. Wallace, personal communication).

During the war, *Pseudomugil signifer* was dispatched from Australia to Port Moresby for use by Malarial Control Units of the Australian Army in Papua and New Guinea (J. L. Wassell, personal communication).

Some attention has been given to the possibility of the biological control of mosquitoes by algae. Following reports overseas that certain algae were lethal to mosquito larvae, Buhôt (81) investigated the effect of *Nitella phauloteles* Groves (Characeae) upon mosquitoes in Queensland, and concluded that oviposition was inhibited by the presence on the water surface of an oily film produced by the plant. Further work on *Nitella phauloteles* and other Queensland Characeae was carried out by Hamlyn-Harris (257, 259) who found no reason to believe that any Charophytes are capable of killing mosquito larvae. Nevertheless, *Nitella* has been distributed to some extent with the object of reducing mosquito infestation. An attempt in 1930 to establish it in the Lakunai swamp in New Guinea was unsuccessful (502). It was also introduced into mosquito breeding sites in New Guinea during the war (70).

No thorough studies have been made of the rôle of fishes in the control of mosquitoes in the Australian region, although the importance of the fish and mosquito species inhabiting the same kind of water (fresh, brackish, salt or polluted; permanent or temporary; densely weeded or not; etc.) has been appreciated, and much is known of the habitats of particular mosquito and fish species. It seems clear that mosquitofish (and possibly other fishes) often give excellent control of mosquitoes in waters which are permanent, not too weedy, and freely accessible in all parts to the fish: also, that their efficiency may be enhanced by periodically restocking impermanent water, and reducing excessive weed growth in channels and swamps, and at water margins. However, even under otherwise favourable conditions, the effectiveness of the fish may be reduced by predators or by the flushing of streams by storm water. Also, when sites such as rain puddles, gutters, holes in trees, and the like, form part of a mosquito's breeding habitat, the influence of fish on its abundance is limited. Though fish can make a significant and even important contribution to the reduction of mosquito numbers, other measures will commonly be necessary. These will include means of reducing the number of mosquito breeding sites, methods of making them less favourable to mosquitoes or more favourable to natural enemies, and direct insecticidal measures.

Australian sources do not make it clear whether *Gambusia* is capable of controlling mosquitoes in brackish and salt water habitats, though it is known (341) that mosquitofish maintain populations in fresh, brackish, and salt water along the Gulf coast of U.S.A.

Sources

66, 70, 73, 74, 76, 81, 90, 91, 109, 110, 111, 112, 113, 114, 177, 257, 258, 259, 273, 341, 455, 460, 480, 494, 502 (1929–40, 1949–50, 1951–2, 1954–5), 503 (1934–5, 1947–8, 1954–5), 544.

In addition to the above sources, the writer has for this review drawn on information provided by the following authorities in personal communications:

Butcher, A. D., Director of Fisheries and Game, Victoria.
Christian, S. H., Malaria Control School, New Guinea.
Dun, G. S., Lowland Agricultural Experiment Station, New Guinea.
Edies, J., Director-General of Medical Services, Tasmania.
Fegan, C. F., City Health Officer, Sydney, N.S.W.
Hale, H. M., South Australian Museum, Adelaide.
Lee, D. J., School of Tropical Medicine, University of Sydney.
Mabbett, J. D., Chief Inspector and Secretary, Department of Health, Brisbane City Council, Queensland.
Marshall, T. C., Department of Harbours and Marine, Brisbane, Queensland.
O'Shea, T., Department of Public Health, Brisbane, Queensland.
Rapson, A. M., Division of Fisheries, New Guinea.
Snow, D. J. R., Commissioner of Public Health, Western Australia.
Southwood, A. R., Director-General of Public Health, South Australia.
Wallace, H. G., Director-General of Public Health, New South Wales.
Wassell, J. L., Coen, Queensland.
Whitley, G. P., Australian Museum, Sydney, N.S.W.
Woodhill, A. R., Department of Zoology, University of Sydney, N.S.W.

(55) **Cattle tick**—*Boophilus microplus* (Can.) (Ixodidae, Acar.)

Twenty specimens of the cattle egret (*Bubulcus ibis coromandus* (Boddaert) (Ardeidae)) were obtained from London in 1933, and eighteen of them were released at Kimberley Downs Station, Western Australia, for the control of cattle tick, but the birds survived scarcely more than a week, falling easy prey to hawks and other enemies (317). It is reported elsewhere (479) that these birds

were introduced by the Pastoralists' Association from Calcutta, but did not succeed in establishing themselves. It is known that *Bubulcus ibis coromandus* is now well established in northern Australia and New South Wales, but the bird is a notorious wanderer and ornithological opinion inclines to the view that its establishment in Australia is probably not the result of the 1933 introduction (493). The cattle egret has presumably had no effect on the abundance of the cattle tick.

The introduction of the starling, *Sturnus vulgaris* L.(Sturnidae) into the north of Western Australia for the control of cattle tick has also been proposed, but not acted upon (317).

Sources
39, 240, 317, 479, 493.

SUMMARY OF RESULTS

It is customary to characterize attempts at biological control as 'successful' or 'unsuccessful', as if the introduction of natural enemies either causes a pest to become innocuous or leaves its importance unchanged. This is an undesirable oversimplification, and the writer, in agreement with H. Compere (108), considers that in practice many different degrees of biological control are attained.

In the oversimplified view, biological control is 'successful' if other forms of control can be dispensed with, and 'unsuccessful' if they cannot. It is expected of 'successful' biological control that the agriculturist will no longer need to concern himself with the former pest. Such standards are not used for other methods of control. An insecticide which gives a good kill is considered to be successful, even though the agriculturist will be faced with recrudescence of the pest soon afterwards. Chemical control is not expected to provide perfect solutions to pest problems, and it is unrealistic to expect biological control to do so. The double standard is primarily a tribute to the extraordinarily high levels of biological control attained against some pests, particularly in certain tropical islands possessing a climate favourable for the continuous development of the hosts and their natural enemies. The concept of 'successful' and 'unsuccessful' biological control should be replaced by the attitude that biological control is required to reduce the loss and trouble caused by pests, and is successful to the extent that it reduces them.

Quantitative evidence concerning the importance of pests is seldom obtained before and after their biological control is attempted. When biological control is highly successful, the diminished importance of the pest is so obvious that the success is acknowledged without demur. On the other hand, when a lesser degree of control is attained, the reduction in pest numbers may easily be attributed to unfavourable weather, improved insecticidal practices, or other factors, and the lower level of infestation may gradually come to be accepted as normal, without any significance being attached to the effect of the natural enemies.

Also, when natural enemies are capable of providing some measure of control but insecticides cannot be dispensed with entirely, the insecticides used commonly reduce the efficacy of the natural enemies. Generally, insecticidal practices are antagonistic to biological control, and there is a growing awareness of the need to resolve this incompatibility. It is only by doing so, that biological factors in control can be brought to maximum effectiveness, and insecticidal schedules can be minimized.

Many pests and incipient pests in Australia and Australian New Guinea are controlled to different degrees by natural enemies. There are many examples of introduced natural enemies reducing the importance of pests, and many native, cosmopolitan, and accidentally introduced parasites and predators undoubtedly play an important rôle in restricting pest abundance.

Biological control investigations in the Australian area have sometimes been protracted and thorough, but have often been purely empirical, and sometimes brief and superficial. No problem has been pursued to the point where all possibilities have been fully explored, though in a few, such as the Australian sheep blowfly, the possibility of future success seems remote in the extreme.

In order to provide a general picture of the contribution of biological control to the reduction of insect problems in Australia and Australian New Guinea, pests whose biological control has been attempted are separated below into several categories based on the success achieved. Such a classification is necessarily tentative. Rigid scientific proof of the success or failure of biological control is

virtually always lacking, and though no one questions the more outstanding successes, the absence of rigid proof leaves room for speculation and disagreement in the less obvious instances. In drawing up the following lists, the writer has been guided predominantly by the published views of the entomologists directly concerned.

Pests, the importance of which has been reduced by deliberate attempts at biological control, are given, approximately in descending order of the success obtained, in the following two lists, (a) and (b). A lower position in the lists does not necessarily imply greater importance as a pest; this depends on the economic importance of the hosts attacked, and many other matters. Also, as the lists are concerned with the success of *deliberate* attempts at biological control, and not with the effects of natural enemies which have not been deliberately introduced or distributed, a lower position in the lists does not necessarily imply a lower level of biological control by natural enemies as a whole. For example, black scale and soft brown scale are probably under more effective biological control than several pests listed above them.

(a) Pests substantially reduced in status

Greenhouse white fly (pp. 28-29)	*Encarsia formosa* is highly effective in all the States concerned.
Woolly aphid (pp. 4-5)	*Aphelinus mali* has greatly reduced its status in all States.
Mealy bugs (pp. 18-19)	*Cryptolaemus montrouzieri* has provided a high degree of control in Western Australia, where it also controls *Eriococcus araucariae* on Norfolk Island pine.
Green vegetable bug (pp. 29-30)	*Microphanurus basalis* has diminished the severity of attack of this bug in most areas.
Black scale (pp. 6, 9-10)	In Western Australia, and possibly elsewhere, introduced natural enemies have contributed greatly to the substantial degree of biological control which is general in Australia.
Vine scale (pp. 14-15)	*Aphycus timberlakei* effectively controls this species in Western Australia and probably elsewhere. In Australia generally this pest seems to be controlled by parasites.
Golden oak scale (p. 39)	*Habrolepis dalmani* has provided a useful measure of control in Tasmania and possibly elsewhere.
Coconut leafminer (p. 23)	*Pleurotropis parvulus* is very effective in the Rabaul area of New Britain and possibly in other parts of the Bismarck Archipelago.

(b) Pests reduced in status

Mosquitoes (pp. 41-46)	*Gambusia affinis* is of distinct value against mosquitoes in some habitats in Australia and New Guinea.
Oak aphid (pp. 38-39)	The parasites distributed (*Aphelinus flavus* and *Tryoxis cirsii*) apparently provide a useful degree of control in Tasmania at least.
Apple leafhopper (pp. 19-20)	*Anagrus armatus nigriventris* seems to be of distinct value in Tasmania.
Soft brown scale (pp. 10-12)	It is probable that introduced species have contributed to the generally effective biological control of this pest in Australia.
Coconut grasshoppers (pp. 3-4)	*Leefmansia bicolor* is of value in the Bismarck Archipelago.
Cabbage moth (pp. 31-32)	Introduced parasites are thought to have reduced appreciably the abundance of this pest.
Cabbage white butterfly (pp. 30-31)	Introduced parasites provide a useful measure of control.
Cabbage aphid (pp. 27-28)	Introduced natural enemies have greatly reduced the severity of attack in Western Australia. (Generally in Australia natural enemies are of importance in its control).

Red scale (pp. 12-14)	*Aphytis chrysomphali* is of value in controlling this species in some areas.
Sweet potato hawk moth (p. 34)	It has been reported that *Bufo marinus* has proved effective.
Lucerne flea (p. 27)	*Biscirus lapidarius* is effective in some areas though it does not generally provide adequate control.

In addition to the abovementioned results, the establishment of *Orcus chalybeus* and *Leis conformis* in Western Australia has provided useful additional polyphagous predators of scales and aphids in that State.

Despite the reduction by introduced natural enemies of the pest status of each of these insects, reliance continues, to different degrees with different species, to be placed on insecticides to provide a fully adequate economic level of control. Some of these insects are still major pests. To take an extreme example, red scale is probably the worst pest of citrus, although entomologists in different States have commented on the capacity of natural enemies to bring infestations under control. In this instance, as in so many others, it is not known to what extent the insecticides used reduce the effectiveness of the natural enemies, though it seems likely that the reduction in efficiency is broadly commensurate with the extent to which insecticides are employed.

The following two lists, (c) and (d), show those species against which natural enemies have been established, probably with little or no effect, (c) includes those insects for which some degree of control by introduced natural enemies has at one time or another been claimed, and (d) includes those for which no such claims have been made.

(c) **Pests of doubtfully diminished status**

Coconut scale (p. 17)	The introduction of unspecified parasites and predators into coral islands in the north-eastern portion of the Territory of New Guinea was briefly reported to have had some beneficial effect.
Banana weevil borer (pp. 22-23)	*Dactylosternum hydrophiloides* may be of some limited value in Queensland.
Cane weevil borer (p. 36)	*Ceromasia sphenophori* has apparently made little or no difference to this problem.
White grubs (pp. 34-36)	*Bufo marinus* is widely established in Queensland, but evidence is lacking that it has significantly reduced the abundance of white grubs.

(d) **Pests of unchanged status**

Coconut leaf Hispa (pp. 23-24)	*Tetrastichus brontispae*, established in New Britain, is apparently of little or no importance.
Potato moth (pp. 33-34)	*Copidosoma koehleri* has not so far been judged to be of value.
Australian sheep blowfly (pp. 39-41)	*Nasonia vitripennis*, established in Western Australia, was ineffective.
Buffalo fly (p. 41)	The presumed establishment of *Spalangia sundaica* in northern Australia was without effect.

There are a number of pests against which natural enemies have been introduced without any becoming established—at least so far as is known with certainty. The thoroughness of the attempts to establish natural enemies varied greatly, and the pests are listed below (e) approximately in the order of the degree of effort made. The list is not complete, a number of the minor attempts at biological control being omitted.

(e) **Pests against which natural enemies have been introduced but not established so far as is known with certainty**

Pine aphid (pp. 37-38)
Queensland fruit fly and Mediterranean fruit fly (pp. 24-26)
Oriental fruit moth (p. 21)
Underground grass grubs (pp. 32-33)
San José scale (p. 17)
Codling moth (pp. 20-21)
White wax scale (pp. 15-16)
Pink wax scale (pp. 16-17)
Pea weevil (p. 37)
Pink sugar-cane mealy bug (p. 27)
Garden snail (p. 37)
Pear and cherry slug (p. 24)

Several pests, whose biological control is being currently investigated, have not been listed above because the work has not reached a sufficiently advanced stage. These include rhinoceros beetle, giant African snail and cacao weevil borer in New Guinea, and vegetable weevil in Australia. Current biological control investigations also include work on cabbage butterfly, cabbage moth, cabbage aphid, green vegetable bug, Queensland fruit fly, white wax scale and pink wax scale in Australia, and mealy bugs in New Guinea.

BIOLOGICAL CONTROL OF WEEDS

GENERAL

There are a number of papers which deal rather broadly with Australian weed problems, and that are concerned wholly or in part with biological control. The more general papers are those by Currie (119–20), and Cashmore and Campbell (89). Papers dealing more particularly with biological control, and concerned to a greater or lesser extent with the principles involved, are those by Tillyard (507, 509), Nicholson (430–1), and Wilson (549–52, 554). Evans (172) provides some information on the biological control of weeds in Australia. Wilson (555) has summarized the results of Australian attempts at the biological control of weeds.

Sources
89, 119, 120, 172, 430, 431, 507, 509, 549, 550, 551, 552, 554, 555.

CONTROL OF SPECIFIC WEED PESTS

In this subsection, Australian work on the biological control of the following weeds is reviewed: prickly pear (*Opuntia* spp.), St. John's wort (*Hypericum perforatum*), lantana (*Lantana camara*), Crofton-weed and mist-flower (*Eupatorium* spp.), gorse (*Ulex europaeus*), Noogoora burr and Bathurst burr (*Xanthium* spp.), ragwort (*Senecio jacobaea*), nut-grass (*Cyperus rotundus*), common heliotrope (*Heliotropium europaeum*), and skeleton weed (*Chondrilla juncea*). The investigations into the biological control of prickly pear, St. John's wort and Noogoora burr were relatively prolonged and extensive though far from exhaustive, but work on the others was very incomplete.

Apart from these weeds, C.S.I.R.O. and Commonwealth Prickly Pear Board officers working overseas have given some attention to the natural enemies of *Argemone mexicana*, *Salvia reflexa*, *Pteridium aquilinum*, *Physalis lanceolata*, and *Bassia* spp. in America, and *Echium* spp., *Inula* spp., *Centaurea* spp. and other thistles in Europe. However, these observations were not pursued to a stage which justifies review in this paper.

(1) **Prickly pear**—*Opuntia* spp. (Cactaceae)

Many species of *Opuntia* are present in Australia, all being of American origin. The two outstanding pest species were the common prickly pear, *O. inermis* (DC.) DC., and the spiny prickly pear, *O. stricta* (Haw.) Haw. Of much less importance were the following species:

Tiger pear—*O. aurantiaca* Lindl.
Velvety tree pear—*O. tomentosa* Salm.-Dyck.
White spine prickly pear—*O. streptacantha* Lam.
Drooping prickly pear—*O. vulgaris* Mill.(*O. monacantha* (Willd.) Haw.)
Devil's rope—*O. imbricata* (Haw.) DC.

The problem was of great magnitude. In 1925, about sixty million acres of land were infested, about half so densely that the land was useless. Some 80 per cent. of the area occupied was in Queensland, and the remainder in New South Wales. The value of the land before improvement varied from five to thirty shillings per acre, and chemical or mechanical control, which cost ten pounds or more per acre, was quite uneconomic.

Introductions of cactus insects have extended over a long period of time. In 1787, Governor Phillip imported into Australia from Argentina a cochineal insect, possibly *Dactylopius ceylonicus* Green (*indicus* Green) (Dactylopiidae), for dye production, but there is no information on its subsequent history or establishment.

An American cactus scale insect, *Diaspis echinocacti* (Bouché), has been established in Australia for many years, apparently having been accidentally introduced. It is found frequently on *Opuntia tomentosa* and sometimes on *O. inermis* and *O. stricta*, but causes very little damage to the host-plants.

The biological control of prickly pear was advocated as early as 1899. In 1903, the Queensland Department of Agriculture and Stock introduced *Dactylopius ceylonicus* from both India and Ceylon, but failed to establish it, perhaps because the wrong host-plant was provided. This insect had been in India since 1795, and had greatly reduced *Opuntia vulgaris* both in India and Ceylon.

In 1912, the Queensland Government appointed a Prickly-Pear Travelling Commission to investigate the control of prickly pear by natural enemies, and during the period 1912–4 the Commission visited India, Ceylon, South Africa, the Mediterranean littoral, North and South America, and the West Indies. In 1913 and 1914, the Commission imported into Australia the following natural enemies of prickly pear:

Dactylopius ceylonicus from Ceylon and northern India

Dactylopius cacti Costa from South Africa

Dactylopius greenii Cock.(*D. confusus capensis*, *D. capensis*) from South Africa

Cactoblastis cactorum (Berg) (Phyticidae) from Argentina

Gloeosporium lunatum Ell. and Er. (Melanconiaceae)—a fungus which causes an anthracnose or shot-hole disease.

Of these, *Dactylopius ceylonicus* was liberated in 1914. It attacked *Opuntia vulgaris* only, and within a few years it largely controlled this pear in Queensland and New South Wales. *Dactylopius greenii* was liberated in Queensland in 1915, but there is no record of its establishment. A culture of *Cactoblastis cactorum* could not be established, and this species was not liberated at that time.

After delays caused by the first world war, the Commonwealth Prickly Pear Board was set up by the Governments of the Commonwealth, New South Wales, and Queensland, to continue this work. The Board operated from 1920 until 1939. The Prickly-Pear Land Commission in Queensland and the Prickly-Pear Destruction Commission in New South Wales participated in the utilization and distribution of the insects established by the Board. The Board's officers explored most of the cactus areas of North and South America, particular attention being given to the United States (Texas, Florida, New Mexico, Arizona, etc.), Mexico, and Argentina. Many cactus species were investigated, and one hundred and fifty to one hundred and sixty cactus insects were found. Of these, forty-eight species were imported into Australia between 1921 and 1935.

There is a complex of insects peculiar to the Cactaceae, and very few of these insects attack other plants. Whole genera, and even groups of related genera, are restricted to cactus plants. Many of these insects, especially the Lepidoptera, confine themselves to particular kinds of cacti, such as the subgenus *Platyopuntia* or *Cylindropuntia*. Some of the insects, especially species of *Dactylopius*, show marked host preferences within the range of hosts attacked. The majority of the Lepidoptera and Coleoptera are borers in the larval stage: most of the external feeders belong to the Hemiptera.

The Prickly Pear Board introduced into Australia the following species:

Species	Introduced	
	Origin	Year
Cactoblastis cactorum	Argentina	1925
Cactoblastis doddi Heinr.	Argentina	1920, 1934, 1935
Melitara prodenialis Walk.(Phyticidae)	Florida, Texas	1921–33
Melitara dentata (Grote)	Colorado	1925–7
Melitara doddalis Dyar	Texas, Arizona	1924–8
Melitara sp.	Texas	1922–9
Olycella junctolineella (Hulst) (Phyticidae)	Texas	1921–3
Tucumania tapiacola Dyar (Phyticidae)	Argentina	1935
Ozamia odiosella (Hulst) (Phyticidae)	Texas	1921–2
Laniifera cyclades Druce (Pyraustidae)	Mexico	1926–7
Mimorista flavidissimalis Grote (Pyraustidae)	Texas	1921–3, 1932
Metapleura potosi Busck (Gelechiidae)	Mexico	1927
Moneilema crassa Le C.(Cerambycidae)	Texas	1925, 1929
Moneilema gigas Le C.	Arizona	1925–6
Moneilema armata Le C.	Texas	1924–6

Species	Introduced: Origin	Introduced: Year
Moneilema rugosipennis Fish.	Mexico	1927
Moneilema laevigata Bland	New Mexico	1925–7
Moneilema corrugans Casey	New Mexico	1926
Moneilema obtusa Le C.	Utah	1926
Moneilema ulkei Horn	Texas	1921–9
Moneilema variolare Thoms.	Mexico	1927–8
Coenopaeus palmeri Le C.(Cerambycidae)	Texas	1925
Lagochirus funestus Thoms.(Cerambycidae)	Mexico	1935
Cactophagus spinolae Gyll.(Curculionidae)	Mexico	1927
Gerstaeckeria doddi Fish.(Curculionidae)	Texas	1921–2
Gerstaeckeria nobilis Le C.	Texas	1921–2
Gerstaeckeria porosi Le C.	Texas	1921–2
Gerstaeckeria hubbardi Le C.	Florida	1921
Gerstaeckeria clathrata Le C.	Texas	1921
Disonycha varicornis Horn (Chrysomelidae)	Texas	1921
Chelinidea vittiger Uhl.(Coreidae)	Florida, Texas	1921–3
Chelinidea canyona Haml.	Texas	1921–3
Chelinidea tabulata Burm.	Texas	1921–3
Narnia pallidicornis Stål.(Coreidae)	Texas	1921–4
Narnia snowi Van Duzee	U.S.A.	1924
Asphondylia opuntiae Felt (Cecidomyiidae)	Texas	1921–9
Copestylum marginatum Say (Syrphidae)	U.S.A.	1921–3
Volucella esuriens F.(Syrphidae)	U.S.A.	1921–3
Volucella pusilla Macq.	U.S.A.	1921–3
Volucella fasciata Macq.	U.S.A.	1921–3
Hermetia illucens L.(Stratiomyidae)	U.S.A.	1921–3
Hermetia chrysopila Loew	U.S.A.	1921–3
Hermetia hunteri Coq.	U.S.A.	1921–3
Dactylopius ceylonicus	Argentina	1925, 1932, 1934
Dactylopius greenii	South Africa	1921
Dactylopius coccus Costa	South Africa	1921
Dactylopius confusus Cock.	Florida	1922–3, 1932
Dactylopius sp. near *confusus* Cock.	Argentina	1932, 1934
Dactylopius opuntiae Licht.(*D. tomentosus*)	California	1920
	Texas	1921–2, 1931–2
	Arizona	1922
	Mexico	1927, 1934
Dactylopius newsteadi Cock.	Texas	1924
Tetranychus opuntiae Banks (Tetranychidae)	? Texas	? 1922–3

Most of the more promising of the introduced species were subjected to food-tests. With the exception of species of *Dactylopius*, all the insects attempted in the larval or adult stage to feed on plants other than cacti. *Mimorista flavidissimalis*, *Ozamia odiosella*, and *Cactophagus spinolae* were able to develop from egg to adult on other plants, and the partly grown larvae of many species completed their development on other hosts.

The following list separates many of the introduced species into various food-test categories, and shows the species liberated, and those established:

Species	Liberated: States	Liberated: Years
(A) Insects unable to develop on any plant other than a cactus		
1. Establishment attempted		
(a) Established		
Cactoblastis cactorum	Queensland, New South Wales	1926–33
Tucumania tapiacola	Queensland, New South Wales	1935–9
Olycella junctolineella	Queensland, New South Wales	1924–7
Moneilema ulkei	Queensland, New South Wales	1926–39
Moneilema variolare	New South Wales	1932–4
Lagochirus funestus	Queensland	1936–40
Chelinidea tabulata	Queensland, New South Wales	1922–9
Chelinidea vittiger	Queensland, New South Wales	1925–9
Dactylopius opuntiae	Queensland, New South Wales	1921–6
Dactylopius newsteadi	Queensland, New South Wales	1925–6
Dactylopius ceylonicus	New South Wales	1935
Dactylopius sp. near *confusus*	Queensland, New South Wales	1933–7

Species	Liberated: States	Liberated: Years
(b) Not established		
Cactoblastis cactorum	South Australia	1934
Melitara prodenialis	Queensland, New South Wales	1928–36
Melitara dentata	Queensland	1927
Melitara doddalis	Queensland, New South Wales	1926–9
Melitara sp.	Queensland, New South Wales	1925–9
Cactoblastis doddi	Queensland	1935, 1936
Dactylopius confusus	Queensland	1933
2. Establishment not attempted (or not seriously attempted) because of low potential value		
Moneilema crassa		
Moneilema armata		
Moneilema laevigata		
Moneilema gigas		
Moneilema rugosipennis		
Coenopaeus palmeri		
Chelinidea canyona	Queensland	1925
Narnia pallidicornis		
(B) Insects feeding or ovipositing on plants other than cactus, and not established in Australia		
Ozamia odiosella		
Mimorista flavidissimalis	Queensland	1925
Metapleura potosi		
Asphondylia opuntiae		
Cactophagus spinolae		
Gerstaeckeria doddi		
(C) Species not tested		
(a) Established		
Tetranychus opuntiae	Queensland, New South Wales (accidental liberations)	? 1922 or 1923
(b) Not established		
Dactylopius greenii	Queensland	1926
Dactylopius coccus	Queensland	1926

The main host-plants in Australia of the species established are:

Species	Main hosts in Australia: *O. inermis*	*O. stricta*	*O. aurantiaca*	*O. streptacantha*	*O. tomentosa*	*O. vulgaris*	*O. imbricata*
Cactoblastis cactorum	X	X	X	X			
Tucumania tapiacola	X		X				
Olycella junctolineella	X	X		X			
Moneilema ulkei	X	X		X	X		
Moneilema variolare	X						
Lagochirus funestus				X	X		
Chelinidea tabulata	X	X		X	X		
Chelinidea vittiger	X	X		X			
Dactylopius opuntiae (various strains)	X	X		X	X	X	
Dactylopius newsteadi							X
Dactylopius ceylonicus						X	
Dactylopius sp. near *confusus*			X				
Tetranychus opuntiae	X						

In the earlier years of the investigation, it was expected that the control of prickly pear by introduced insects would be a gradual process, in which the dense areas would be thinned, individual

plants destroyed, and fruiting and rate of spread reduced. The original plan was to establish an insect complex of many species. No one anticipated the extraordinary collapse of vast areas of prickly pear within a few years following the establishment of *Cactoblastis cactorum*. By 1928, it was apparent that this insect would bring about the destruction of the two main pest species, *O. inermis* and *O. stricta*. However, it is considered that, even if *Cactoblastis cactorum* had not been introduced, other insects would have exercised a valuable measure of control.

The results obtained against the two main species, *O. inermis* and *O. stricta*, were highly satisfactory. The establishment of *Chelinidea tabulata*, *Dactylopius* spp. and *Tetranychus opuntiae* had already given promising results by 1927. The introduction and general distribution of *Cactoblastis cactorum* during 1925–30, however, led to the destruction of most of the original stands of *inermis* and *stricta* in 1930–2. In the next year, starvation caused a great reduction in the numbers of *Cactoblastis cactorum* and there was much regrowth of prickly pear, but during 1933–5 *Cactoblastis cactorum* increased in numbers and brought about a further host decline. The position became relatively stable in the next few years, with virtually complete control of these two prickly pears in Queensland. During this process, competition by *Cactoblastis cactorum* caused a marked fall in the numbers of *Chelinidea tabulata*, *Dactylopius* spp. and *Tetranychus opuntiae*, which ceased to have any importance in the control of *O. inermis* and *O. stricta*. In northern New South Wales, *Cactoblastis cactorum* reduced large areas of dense prickly pear to scattered plants, making it possible to kill the remainder by weedicides at reasonably low cost. In isolated areas in the north of the State and in all areas below about latitude 32° South, *Cactoblastis cactorum* was quite ineffective. *Dactylopius opuntiae*, by destroying the fruit of *O. inermis*, has probably prevented the spread of the plant by seeds in some areas of New South Wales, but has generally been of little use.

A subsidiary problem has been the occurrence of resistant forms of *Opuntia inermis* and, to a lesser extent, *O. stricta*. The more common resistant form was the chlorotic 'yellow pear' found on poor soils, usually on hilly, timbered country, chiefly in New South Wales. When nitrogen was supplied, yellow pear became green and was more readily destroyed by *Cactoblastis cactorum*. By killing the standing timber, which absorbed most of the available nitrogen, the acreage of yellow pear was greatly reduced. The less important resistant form possessed thick segments, and was highly mucilaginous, with a high carbohydrate content. The younger growth was suitable for food, but the larvae were unable to survive in the older starchy segments. Destruction of this resistant form required several successive attacks by *Cactoblastis cactorum*.

Of the minor species of *Opuntia*, *O. aurantiaca* is the most important. It is widely distributed in Queensland, and is now the major pear pest in New South Wales. *Cactoblastis cactorum* destroys the narrow segments but does not penetrate into the underground bulbs, and, although small plants are often killed, *Cactoblastis cactorum* does not provide effective control. *Tucumania tapiacola*, introduced for the control of *O. aurantiaca*, has not proved effective. However, satisfactory control of this pear in Queensland has been provided by *Dactylopius* sp. near *confusus*. This insect has reduced the formerly extensive areas of *O. aurantiaca* to scattered infestations. Local increase of this pear is common, and artificial distribution of the insect is necessary. In New South Wales, *O. aurantiaca* has been less well controlled by *Dactylopius* sp. near *confusus* but this insect is extensively used for its control and is systematically distributed each season in infested areas. It is reasonably successful in the north of the State.

Brookes (80) records *Dactylopius* sp., closely resembling *D. confusus* Cockerell as defined by Ferris, occurring on *Opuntia megacantha* Salm.-Dyck. in South Australia in 1956, the original introduction having been made with material obtained from the Commonwealth Prickly Pear Board, Queensland. A. P. Dodd (personal communication) comments on this record as follows: "This cochineal would undoubtedly be what we have called *D. opuntiae*, established in Queensland on *O. streptacantha* and *O. megacantha* from material introduced from Mexico. It could not be what we refer to as *Dactylopius* sp. near *confusus*, introduced from the Argentine for the control of *O. aurantiaca*".

Opuntia streptacantha occurs principally in central Queensland. *Cactoblastis cactorum* causes limited damage to it, young plants and young terminal segments of older plants being frequently

destroyed, but segments more than a year old are resistant to attack. The Mexican strain of *Dactylopius opuntiae* has greatly reduced the undergrowth of seedlings and young plants, and, although the large plants suffer little damage, they are destroyed by *Dactylopius opuntiae* if they are first cut down. *Lagochirus funestus* also causes marked damage to *O. streptacantha*. *Moneilema ulkei* has adversely affected this species in some localities, but does not control it effectively.

Young plants of *Opuntia tomentosa* growing among *O. inermis* and *O. stricta* are readily destroyed by *Cactoblastis cactorum*. The moth, however, seldom oviposits on the seedlings and young plants of *O. tomentosa*, and never oviposits on the older plants. In consequence, this plant is generally immune from attack by *Cactoblastis cactorum*. *Lagochirus funestus* has caused much damage to *O. tomentosa* in central Queensland, and *Moneilema ulkei* also attacks it, but without significant effect. The strain of *Dactylopius opuntiae* which attacks *O. inermis* and *O. stricta* is efficient in controlling the seedlings and young plants of *O. tomentosa*. This prickly pear now rarely succeeds in developing dense infestations except in brigalow scrubs, and even under these conditions *Dactylopius opuntiae* exercises efficient though gradual control. Nevertheless, there has been a very marked increase of seedlings and young plants of *O. tomentosa* in the more hilly sections of the Toowoomba-Gatton district, where *Dactylopius opuntiae* is not successful in destroying this plant in open and light-timbered country.

Opuntia vulgaris in Queensland and New South Wales was largely controlled in a few years by *Dactylopius ceylonicus* after its introduction in 1913. The re-introduction of *Dactylopius ceylonicus* (from Argentina in 1925, 1932 and 1934) and its liberation in New South Wales in 1935 were for the purpose of controlling *Opuntia aurantiaca*. *Dactylopius ceylonicus* occurs on a number of species of *Opuntia* in Argentina, and some of these are closely related to *O. aurantiaca*. The strain imported in 1934 and liberated in 1935 was transferred to *O. aurantiaca* in Australia, but its rate of increase on this host was slow, and it did not survive in the field.

Dactylopius ceylonicus on *Opuntia vulgaris* was sent from Queensland to Victoria in 1925, and to South Australia in 1934, the origin of the insects being either the 1913 introduction from Ceylon or the 1925 introduction from the Argentine (A. P. Dodd, personal communication). In both these States, *D. ceylonicus* has destroyed small patches of *Opuntia vulgaris*.

Opuntia imbricata occurred in small areas in New South Wales and Queensland. *Dactylopius newsteadi* caused striking damage to this species, reducing particularly the number of seedlings and young plants, but it is very susceptible to attack by *Cryptolaemus montrouzieri*, and most *O. imbricata* was subsequently eradicated by poisoning and mechanical means. *D. newsteadi* survives on the remaining plants and kills seedlings as they appear.

The diseases of the Cactaceae were also investigated to some extent both in America and Australia. Of the many diseases of prickly pear, a few are capable of causing considerable damage, but they rarely bring about the death of infected plants unless assisted by insects. Secondary parasitic organisms are of greater importance than the primary diseases. In Australia, bacterial soft rot often accompanies infestation by *Cactoblastis cactorum* in the upper segments of prickly pear. The disease can pass from segment to segment only if transported by the insects, and it is restricted to the succulent growth, the thick basal portions of the plant being immune. In consequence, even with the assistance of the insects, the disease cannot produce complete disintegration of the host except in young plants. This disease is more common at some times of the year than at others, but even when most common it does not accompany much of the insect attack. It is not considered that disease played an important part in the control of prickly pear by *Cactoblastis cactorum*.

Sources

1, 2, 32, 61, 69, 80, 138, 139, 140, 141, 142, 143, 144, 145, 146, 220, 226, 249, 250, 251, 252, 253, 254, 255, 256, 323, 325, 326, 327, 328, 330, 333, 402 (1916, 1920–33, 1938–9), 430, 466 (1912–6), 471 (1932–57), 472 (1924–32), 473, 475, 478, 498, 514, 517, 518, 519.

(2) St. John's wort—*Hypericum perforatum* L. var. *angustifolium* DC. (Guttiferae)

This palaearctic perennial is present in all Australian States except Queensland, and is particularly abundant in Victoria, where it extends over a large area of hill and high plains country of fairly high

rainfall. *Hypericum perforatum* is poisonous to sheep, and is a competitor of pastures and crops. It can be combatted by weedicides and improved pastures.

Work on the biological control of St. John's wort was undertaken by C.S.I.R. After preliminary enquiries, the investigations were begun in England in 1928 and continued there for some years. When it seemed that the insects being studied could not be established in Australia, the work was extended to southern France, where it continued from 1935–40 (548).

About thirty-seven monophagous and oligophagous insects are known to occur on *Hypericum*, and twenty-five of these were investigated, besides many polyphagous insects. The species present on *Hypericum* differ greatly in different climatic areas. Eight insects were selected as being of particular importance in England, and five in southern France. None was common to both groups.

The following species were introduced into Australia:

Species	Introduced	
	Origin	Years
Chrysomela (*Chrysolina*) *varians* Schall.(Chrysomelidae)	England	1929–33
Chrysomela brunsvicensis Grav.	England	1929–35
Chrysomela hyperici (Forst.)	England	1930–4
Chrysomela quadrigemina Suffr. (*gemellata* Rossi, *geminata* Payk.)	France	1937–9
Agrilus hyperici (Cr.) (Buprestidae)	France	1938–40
Lathronympha hypericana Hubn.(Eucosmidae)	England	1930–6
Depressaria hypericella Hubn.(Oecophoridae)	England	1932–6
Anaitis plagiata L.(Geometridae)	England	1932–7
Anaitis efformata Guén.	England	1932–7
	France	1938, 1939
Actinotia hyperici Schiff.(Noctuidae)	France	1939, 1940
Aphis chloris Koch (Aphididae)	England	1932–4
Zeuxidiplosis giardi Kieff.(Cecidomyiidae)	France	1939, 1940, 1950
	California	1953

A record (123) of the introduction from England into Australia in 1929 of *Chrysomela didymata* Scriba is erroneous; the species introduced on that occasion was *C. brunsvicensis*.

All the species imported, as well as some other *Hypericum* insects, were tested for host restriction and found to be highly specific: none was reared from egg to adult on plants other than species of *Hypericum*. There are many western European insects which can be used for the control of St. John's wort without risk to economic plants, and there are doubtless many others in north Africa eastern Europe, and Asia.

Some of the species listed above (*Actinotia hyperici*, *Lathronympha hypericana*, *Depressaria hypericella*, and *Aphis chloris*) were not liberated, either because it seemed unlikely that they would be effective, or because doubts were felt about the absolute safety of the introduction.

The following species were liberated:

Species	Liberated	
	States	Years
Chrysomela hyperici	Victoria	1930–4
Chrysomela varians	Victoria	1930–3
	New South Wales	1930
Chrysomela brunsvicensis	Victoria	1930–4
	New South Wales	1930
Chrysomela quadrigemina	Victoria	1938, 1939
Agrilus hyperici	Victoria	1939, 1940
	New South Wales	1940
Anaitis efformata, *Anaitis plagiata*	Victoria	1933–8
Zeuxidiplosis giardi	New South Wales	1953, 1954
	Victoria	1954, 1955

Both species of *Anaitis* were liberated, but the material released was not recorded specifically, partly because the caterpillars of the two species could not be distinguished.

Of the eight species liberated, *Chrysomela varians*, *C. brunsvicensis*, *Anaitis efformata*, and *A. plagiata* did not become established, and this was attributed to predation by insects, spiders and birds, and to an unfavourable physical environment. The same conclusion was reached concerning the establishment of *Chrysomela hyperici*, which subsequently reappeared. Each of these species was liberated in some thousands, but it is possible that they might have been established if still larger liberations had been made to overcome the initial effects of predation and other adverse influences.

Chrysomela hyperici reappeared in 1939 after an interval of five years, and *Chrysomela quadrigemina* reappeared in 1942 after an interval of two years. Within a few years both became extremely numerous and have remained so ever since, though *C. quadrigemina* is generally the predominant species. The density of these insects is sometimes so great that more than a million beetles can be collected in a few hours from a few acres of *Hypericum*. Complete defoliation of the host-plant by the adults and larvae is common.

These two beetles, after their establishment in Victoria, were redistributed to other areas by C.S.I.R.O., the Victorian Department of Lands and Survey, and other organizations, and over ten million beetles have been transferred to other areas in Victoria (1940–51), New South Wales (1941–56), South Australia (1943–9), Western Australia (1947–53), and Tasmania (1943).

Studies in the Bright district of Victoria (92) showed that conditions were generally near the limit of tolerance of both *Chrysomela quadrigemina* and *C. hyperici*, and that the beetles did not colonize timbered areas. In the most favourable sites, both species are able to multiply within a few years to a density high enough to cause complete defoliation of the weed, which usually dies out, but frequently regenerates almost completely from seed before the beetles become sufficiently numerous to defoliate it again. Where other weed-controlling agencies are lacking, the insects have caused their host-plant to fluctuate violently in density in both time and space without producing a great overall reduction in quantity. By destroying stands of *Hypericum* in areas in which the soils are capable of growing a dense pasture, the insects have paved the way for successful wort control by other factors, *e.g.*, shade-producing herbage and grazing animals.

It was observed in a New South Wales colony site that the gradual multiplication of *Chrysomela hyperici* led to great destruction of the weed in places, but this was soon followed by regeneration. The ability of St. John's wort to maintain its position of predominance in the community in the face of heavy insect damage was due partly to the absence of effective plant competitors. The heavy grazing by rabbits and kangaroos on the plants associated with the weed, and their habit of removing the ground cover by scratching, favoured the regeneration of *Hypericum* (93).

A survey of the effect of the chrysomelid beetles throughout Victoria led to the conclusion that most of the St. John's wort on cleared ground had been effectively controlled. Farmers generally had appreciated the need to follow insect attack by top-dressing and pasture improvement, and this had resulted in many areas which were heavily infested being brought back into full production. The beetles were generally not so effective in timbered country as in open country. It was concluded that there was no doubt that the combination of biological control by the chrysomelid beetles, with hormone type weedicides and pasture improvement, had relieved Victoria of one of its worst weed problems (456).

The most recent statement on the situation in Victoria (457) stresses the limitations in the beneficial effects of the chrysomelids. In open country, their work has been spectacular in many places, but where it has been impossible to follow up these successes with pasture improvement, as on Crown lands or gold dredgings, the weed frequently becomes re-established. Whether the beetles can exercise worthwhile control on these areas in the future remains to be seen. The chrysomelids are not effective in timbered country, and this is a major problem as much of the Crown land infested with St. John's wort is heavily timbered.

It is believed that both chrysomelids are well established in New South Wales, South Australia, and Western Australia, but in Tasmania *Chrysomela hyperici* only has been introduced and established. Defoliation of stands of St. John's wort has been reported from all these States except Tasmania. There has been no general survey of the effect of the chrysomelids on the abundance of St. John's wort in New South Wales, but presumably the beetles have been less effective in this State than in

Victoria. In South Australia (D. C. Swan, personal communication), the beetles have produced a substantial reduction in the abundance of St. John's wort in some localities, notably in the Yankalilla district, but in timbered localities (*e.g.* the National Park) no significant reduction has occurred. It is reported from the Office of the Commissioners of the National Park (R. W. Lyon, personal communication) that the beetles have been moderately successful in controlling the weed in open country in the National Park.

Agrilus hyperici is established at several points in Victoria and New South Wales, and some host-plants have been killed by it, but apparently this species has not yet become widespread or made a significant contribution to the control of St. John's wort. To some extent, this may be the result of severe competition by the chrysomelids. *Agrilus hyperici* has not been liberated in the other States.

Zeuxidiplosis giardi has been liberated only in New South Wales and Victoria. It is established in both States, but its numbers in the field are not yet great enough to have caused any marked effect on the host.

Work on St. John's wort is not at present being pursued intensively. It will be some years before the effects of the introduced insects are fully apparent. If desired, other insect species could be readily introduced.

Sources

56, 89, 92, 93, 94, 97 (1948–57), 116 (1926–48), 119, 120, 121, 123, 402 (1949–50), 403 (1951–3), 431, 433, 454, 456, 457, 506, 507, 509, 522, 531 (1943–9), 533 (1943–7), 542 (1947–51), 547, 548, 549, 550, 551, 552, 553, 554, 556.

(3) **Lantana**—*Lantana camara* L.(Verbenaceae)

This Central American perennial is very abundant in tropical and sub-tropical Queensland and New South Wales. It is regarded as being particularly serious in Queensland, where it is present from the southern border to the most northern settled areas. The most serious infestations in Queensland are in four regions, Cooktown to Ingham, Mackay, Mt. Morgan to the southern border, and the eastern scarp of the Main Range south of Crow's Nest. This weed is also abundant on Norfolk Island.

Lantana occurs over a very large area and hinders proper land use. However, it is considered to be of value in regenerating old banana plantations, and preventing erosion. It is controlled by weedicides, burning, and the use of competing plants.

Following earlier Hawaiian investigations into the biological control of lantana, the Queensland Department of Agriculture and Stock introduced the following lantana insects:

Species	Introduced		Liberation
	Origin	Year	
Agromyza lantanae (Frogg.) (Agromyzidae)	Hawaii	1914	1914
	Hawaii, Fiji	1917	1917
Epinotia (*Crocidosema*) *lantana* (Busck) (*Eucosma polyphaea* Turner) (Olethreutidae)	Hawaii	1914, 1917	1914
Eutreta sparsa Wied.(Trypetidae)	Hawaii	1914	1914
Thecla agra Hew.(Lycaenidae)	Hawaii	1914	1914

The lantana seed-fly (*Agromyza lantanae*) was established from the 1917 liberations at Cairns, the 1914 introductions having failed. Within a year or so, it occurred from the Mossman River in the north to Sydney in the south, although possibly it had been liberated in New South Wales (where its introduction was opposed) only on the north coast. It soon became generally distributed in the lantana areas of both States.

In Queensland, some twenty-five years after the introduction, it was considered that the seed-fly had no effect on already established plants, but that the feeding of the maggots within the berries reduced seed-production, and made the berries less attractive to birds which distribute the seeds. The general effect was thought to be to slow down the rate of spread of lantana, without preventing it from spreading and flourishing.

In New South Wales, the lantana seed-fly is widespread in the North Coast districts and in the vicinity of Sydney, and has been reported to cause considerable damage to lantana fruits on the North Coast.

Epinotia lantana is also established. It is widely distributed along the east coast of Australia, being recorded from Cairns and Brisbane in Queensland and from the North Coast districts of New South Wales. In Queensland at least, this moth is not considered of any use in the control of lantana.

Neither *Eutreta sparsa* nor *Thecla agra* is thought to be established.

L. F. Hitchcock (unpublished records) has reported *Lobesia physophora* (Lower) (Olethreutidae) from lantana berries and receptacles in the Brisbane area. He has also recorded *Platyptilia taprobanes* Feld.(Pterophoridae) on *Lantana camara* in Queensland, the identification being made by A. J. Turner, whose unpublished catalogue states that this species occurs from the Gulf of Carpentaria to Sydney, New South Wales, besides occurring in many tropical areas of the world.

The lantana bug, *Teleonemia scrupulosa* Stål (Tingidae) was introduced by C.S.I.R. from Fiji in 1935 and 1936. A culture was maintained at Canberra for several years, and liberations were made in Queensland (1936–8), New South Wales (1936–40), and Norfolk Island (1937–9). It was also sent from Queensland to New South Wales about 1945, and to Norfolk Island in 1948.

In Queensland, *Teleonemia scrupulosa* was distributed by the Queensland Department of Agriculture and Stock until 1946–7. By 1947, it was present throughout coastal Queensland from the New South Wales border to the far north, and had penetrated inland to Toowoomba. It was quickly established north of Townsville, and in that region the populations were sometimes sufficiently great to inhibit flowering, destroy the top growth of the weeds, and even to kill plants. Further south, the effect of *T. scrupulosa* was less marked. In general in Queensland, but more particularly in the north, the bug appeared to be capable of checking the growth of lantana. However, this early promise has not been fulfilled, and no importance is now attached to the effect of *T. scrupulosa* on lantana in Queensland.

In New South Wales, *T. scrupulosa* is established in the general area of the Tweed, Brunswick and Richmond Rivers, and occurs as far south as Raleigh, near Coff's Harbour. Though reports are periodically made of lantana being defoliated and even killed by lantana bug in this area, *T. scrupulosa* has not provided any important measure of control.

The 1937–9 liberations of *T. scrupulosa* in Norfolk Island were unsuccessful. The bug was, however, established by consignments sent by C.S.I.R.O. from Queensland in 1948. The prospect of establishment was not considered to be good as winter temperatures fall to about 40°F., but the liberation was made in a sheltered part of the island, and the bugs multiplied rapidly. Since that time, the bug has had a considerable effect on lantana, causing widespread defoliation, stem die-back, retardation of growth, reduction of seed, and some mortality. However, the bug population falls greatly during the winter, and it requires most of the succeeding summer to regain a density damaging to the host. It has been reported recently that, although it is not thought that many plants have been killed by the bugs, many clumps of lantana have been so retarded in growth that eradication by mechanical means would now be very much easier.

Work on the biological control of *Lantana camara* was resumed in 1953–4, when Australia collaborated with Hawaii in exploration of the Central American region for insect enemies of lantana. An officer of the Queensland Department of Public Lands participated in this work. Many insect species were despatched to Hawaii and there released in the field or maintained in quarantine. In 1956, an officer of the Department was sent to Hawaii to carry out food-tests with the various lantana insects available for introduction into Australia.

At the conclusion of these tests, the following species were introduced into quarantine in Australia:

Species	Introduced		Liberated
	Origin	Year	
Catabena esula Druce (Noctuidae)	Hawaii	1956	
Diastema tigris Guén.(Noctuidae)	California	1957	1957
Syngamia haemorrhoidalis Guén.(Pyraustidae)	Hawaii	1956, 1957	
	Hawaii	1956	

The liberation of *Catabena esula* was made in Queensland. The work is continuing.

Sources
30, 31, 89, 96, 97 (1948–9, 1952–7), 116 (1929–30, 1935–45), 119, 122, 149, 219, 222, 235, 243, 282, 297, 374, 402 (1949–50), 403 (1947–51, 1952–3), 469 (1913–5, 1916–7, 1918–9, 1937–45, 1946–7, 1952–3), 471 (1950–7), 526, 529, 554.

(4) **Crofton-weed**—*Eupatorium adenophorum* Sprang. and **Mist-flower**—*Eupatorium riparium* Regel (Compositae)

These two Central American perennials are weeds of importance in Queensland and New South Wales. The areas infested are extending, and both species are causing concern. Crofton-weed, which cannot be controlled chemically, is the more serious pest, especially in Queensland.

In consultation with C.S.I.R.O., the Queensland Department of Public Lands in 1952 introduced *Procecidochares utilis* Stone (Trypetidae) from Hawaii. The only known host of this stem gall-fly is *Eupatorium adenophorum*. The fly was distributed in the south-eastern districts of Queensland in 1952–4, became established immediately, and by 1954 occurred almost wherever Crofton-weed was present in the State. *Procecidochares utilis* is heavily attacked by native parasites, particularly *Megastigmus* sp.(Torymidae), and this appears to have prevented the gall-fly attaining a high population density. Nevertheless, an adverse effect on Crofton-weed has been observed, and in certain areas the gall-fly has reduced flowering, seeding, and plant vigour. No reports of the spread of Crofton-weed have been made in the last few years, and the apparent cessation of spread may be the result of the establishment of *Procecidochares utilis*.

The gall-fly was liberated in New South Wales in 1953 and 1954. It spread rapidly, particularly on the north coast. No marked effects on the host have yet been observed, but it has been suggested that the weed is weakened by attack and that its powers of competition are reduced. That complaints concerning Crofton-weed have almost ceased, except so far as Crown lands are concerned, has been attributed to this introduction. *Procecidochares utilis* is now quite common at Roseville, near Sydney.

A fungal disease of the leaves of Crofton-weed became prominent in Queensland in 1954. At times this disease causes much defoliation, especially, it seems, in areas where the gall-fly has been most abundant in previous years. The disease does not affect mist-flower in Queensland. The Department of Agriculture and Stock considers this fungus to be *Cercospora eupatorii* Peck (Dematiaceae), which attacks various species of *Eupatorium* in the United States (A. P. Dodd, personal communication).

Other insect enemies of *Eupatorium adenophorum* are known from Hawaiian investigations, and it may be decided to introduce some of them. Insects may also be imported later for the control of *Eupatorium riparium*, but little is known at present of the species associated with this weed.

Dihammus argentatus Auriv.(Cerambycidae), a native stem and root borer, attacks Crofton-weed in both Queensland and New South Wales. Infestations are sometimes severe. The vigour and growth of the infested plants are affected, and apparently some are killed. In New South Wales an unidentified cerambycid root borer attacks mist-flower, causing some mortality.

Sources
97 (1952–3, 1956–7), 147, 354, 403 (1949–50, 1951–2, 1953–4), 471 (1950–7), 554.

(5) **Gorse**—*Ulex europaeus* L.(Leguminosae)

Gorse is widely distributed in Tasmania and Victoria, in both of which it is of importance though not among the most serious weeds. It occurs also in South Australia. Gorse has some use as a hedge plant; the young plants provide fodder for sheep, and it is a soil nitrogenizer.

The Tasmanian Department of Agriculture introduced the gorse seed weevil, *Apion ulicis* (Forst.) (Curculionidae), from New Zealand in 1939. The object of the introduction was limitation of the spread of gorse by restricting seed production, rather than reduction of the existing quantity. *Apion ulicis* rapidly established itself, and has spread a considerable distance from the liberation

areas. There is as yet no evidence that it has reduced the rate of spread. Other insect enemies of gorse occur in Europe, but because of the limited measure of control desired, it seems unlikely that these will be introduced.

Sources
169, 501 (1938–41, 1942–3, 1947–8).

(6) **Noogoora burr**—*Xanthium pungens* Wallr. and **Bathurst burr**—*Xanthium spinosum* L. (Compositae)

Noogoora burr is perhaps the most serious weed in Australia. An annual of North American origin, it now extends over a very large area of grazing country in Queensland and New South Wales, and also occurs in the other mainland States. It is most important in Queensland, where it has been present since about 1860. It occurs in the flood plains of streams and other suitable locations over the greater part of Queensland from the Gulf of Carpentaria southwards, and down into New South Wales as far south as Sydney. Noogoora burr causes considerable economic loss, its burrs adhering to sheep and reducing the value of the wool subsequently clipped. In addition, it displaces pasture and, at the cotyledon stage of growth, is poisonous to stock.

Noogoora burr can be killed readily by weedicides, but its control by this means presents an immense problem because of the huge areas involved. The relative inaccessability and low value of much of the infested land often make the cost of chemical control prohibitive, and the presence of trees reduces the effectiveness of aerial spraying along water-courses. Noogoora burr has no fodder value, and its biological control has long been considered very desirable.

C.S.I.R. initiated work on the biological control of this weed, and the Commonwealth Prickly Pear Board later participated in the investigation. Field studies were begun in Kansas, U.S.A., in 1929, and after a thorough investigation of this area, the study centre was transferred in 1936 to Texas. Field observations were also made in other parts of America, including the southern States from Florida to California, Mexico and Argentina. In 1938–40 the work was extended to India (Punjab, Central India, United Provinces, Central Provinces and Assam). In this field work, attention was given to any species of *Xanthium* present in the areas visited. The species chiefly encountered were considered to be *Xanthium pungens* (*X. chinense*), *X. pennsylvanicum* and *X. spinosum* in U.S.A., and *X. strumarium* in India.

In the United States about eighty insects were found to attack species of *Xanthium*, each part of the plant being damaged by a number of species. Many of the insects were abundant on *Xanthium*, and caused marked injury to it. In India, on the other hand, the insects associated with *Xanthium* were few, and only one seemed to be of consequence. The following were considered most important:

United States of America

Euaresta aequalis Loew (Trypetidae)—seed destroyer
Cylindrocopturus adspersus Le C.(Curculionidae)—stem borer
Dectes spinosus Say (Cerambycidae) } possibly synonymous—stem borer and pruner
Dectes brevisetosus Casey }
Ataxia hubbardi Fish.(Cerambycidae)—stem borer
Mecas saturnina Le C.(Cerambycidae)—stem borer and girdler
Baris callida Casey (Curculionidae) } possibly synonymous—root borer
Baris interstitialis Say }
Rhodobaenus tredecimpunctatus Ill.(Curculionidae)—stem borer

India

Nupserha antennata Gahan (Cerambycidae)—stem borer

The following species were imported into quarantine in Australia:

Species	Introduced
Euaresta aequalis	1930–40
Baris callida	1933–9
Baris interstitialis	
Cylindrocopturus adspersus	1933–5
Dectes spinosus	1936–7
Dectes brevisetosus	
Ataxia hubbardi	1936
Mecas saturnina	1936–7
Nupserha antennata	1939

Food tests carried out in the United States and Australia on these species and others showed that nearly all *Xanthium* insects attack plants of other genera of the Compositae, and some attack plants of other families.

The only insect considered to be restricted to *Xanthium* was *Euaresta aequalis*, and this was the only species liberated. Liberations were made in southern and central Queensland during the years 1932–40 by the Queensland Department of Agriculture and Stock and the Commonwealth Prickly Pear Board. *Euaresta aequalis* became established only in the vicinity of Brisbane, where it occurs at low densities and has not contributed to the control of Noogoora burr.

In the field, some of the other *Xanthium* insects were found to attack only a few other composite plants (such as ragweed (*Ambrosia* spp.) and wild sunflower (*Helianthus annuus*)), but the more polyphagous insects also attacked other composites (such as cultivated sunflower (*Helianthus annuus*), Jerusalem artichoke (*Helianthus tuberosum*), lettuce (*Lactuca*), *Eupatorium*, *Argemone*, *Gaillardia*, and *Calendula*), and even plants outside the Compositae, such as *Brassica* (Cruciferae) and *Croton capitatus* (Euphorbiaceae). In laboratory tests, the insects attacked a wider range of hosts, and several of such plants as Jerusalem artichoke, cultivated sunflower, chrysanthemum, cosmos, marigold or other garden composites were eaten by even the less polyphagous species, while some of the more polyphagous attacked important economic plants, such as carrot, soybean and potato. The fact that even the least polyphagous of these insects attacked a number of useful plants in laboratory tests has so far prevented the liberation of any of them. Whether or not the possibility of controlling such an important weed as Noogoora burr justifies the liberation of insects which might attack useful plants is at present under consideration.

Work on the biological control of Noogoora burr was renewed in 1957 by C.S.I.R.O. and Queensland authorities. The Department of Public Lands in 1957 imported into Queensland *Mecas saturnina* from the United States and *Nupserha antennata* from India. These insects are to be maintained in quarantine pending the results of experiments on the prospects of one or both being able to control Noogoora burr effectively. If these insects offer substantial promise of being effective, and it is considered that they will not become pests of any importance, they may be liberated in the field.

Noogoora burr is attacked in Queensland by a stem borer, *Prosoplus misellus* Pasc.(Cerambycidae), and in New South Wales by an unidentified pyraustid borer and *Haltica ignea* Blackb.(Halticidae), large numbers of the last named being reported to kill young plants by devouring the leaves.

Bathurst burr is a major weed in all the mainland States of Australia. The presence of its burrs reduces the market value of wool. Although it is very widespread, Bathurst burr does not present the same concentrated problem as Noogoora burr, and it can be controlled with less difficulty by weedicides or controlled grazing. However, it is more important than Noogoora burr in all the mainland States except Queensland. Bathurst burr is now more or less cosmopolitan, but probably originates in South America. It is believed to have been introduced into Australia from Chile about 1840.

During the field investigations of the insect enemies of *Xanthium*, few species were recorded from *X. spinosum*, no doubt because of the limited exploration carried out in South America. *Camaromyia bullans* Wied.(Trypetidae) was reared from *X. spinosum* in Chile and the United States, two curculionids were found to attack it in Argentina, and *Baris callida* was reared from it in the United States.

No insects have so far been deliberately introduced into Australia for the control of Bathurst burr. *Camaromyia bullans* was discovered in New South Wales in 1928, and is presumed to have been introduced inadvertently from South America. This seed-fly is widely distributed and abundant in both Queensland and New South Wales. It destroys large numbers of Bathurst burr seeds and is periodically reported to destroy fairly extensive areas of Bathurst burr, though apparently without having any important general effect on the abundance of the weed.

Other insects attacking Bathurst burr in Queensland (A. P. Dodd, personal communication) are the native stem borers *Zygrita diva* Thoms.(Cerambycidae), *Corrhenes paulla* Germ.(Cerambycidae), and *Lixus tasmanicus* Germ.(Curculionidae). Of these, *Corrhenes paulla* is widely distributed, and has occasionally caused considerable mortality in some localities.

An anthracnose and seedling blight, caused by the fungus *Colletotrichum xanthii* Halst.(Melanconiaceae), resulted in serious damage to Bathurst burr in the summer rainfall region of New South Wales in 1948–51, killing large numbers of seedlings and plants, and greatly reducing the production of burrs. The disease is favoured by prolonged periods of wet weather in the summer and autumn. It has been artificially established in districts where it had not been previously observed, and during three seasons has largely removed the need for spraying and hand cutting the weed on many properties in northern New South Wales. It is considered to be the most useful parasitic disease of a weed ever encountered in this State. The economic value of the disease is at present difficult to assess. The fungus appears to be restricted to hosts of the genus *Xanthium*. It was first described from another species of the genus in New Jersey, U.S.A. *Xanthium pungens* seems to be highly resistant to it, seedlings in infection tests showing only slight symptoms. The disease has not been found on *Xanthium pungens* in the field. (83).

Sources

36, 83, 89, 116 (1928–41), 117, 119, 120, 148, 336, 372, 373, 403 (1948–9, 1950–1), 469 (1933–5), 471 (1942–6, 1949–57), 507, 543, 554.

(7) **Ragwort**—*Senecio jacobaea* L.(Compositae)

Ragwort is a weed of importance in the higher rainfall districts of South Gippsland and Otway in Victoria, and also, to a lesser degree, in South Australia and Tasmania. The area involved is relatively small. Ragwort is poisonous to sheep and cattle, and infests pasture land and adjacent areas of bushland.

C.S.I.R. made the following insect introductions for the control of this weed:

Species	Introduced		Liberated
	Origin	Years	
Callimorpha (*Tyria*) *jacobaeae* (L.) (Arctiidae)	New Zealand	1929–32	1930–2
	England	1934, 1936, 1937	1934, 1936, 1937
Hylemyia (*Pegohylemyia*) *seneciella* (Meade) (Muscidae)	New Zealand	1933	Not liberated
	England	1934, 1936	Not liberated

The liberations of *Callimorpha jacobaeae* were made in South Gippsland and Beech Forest (Victoria). It was virtually impossible to breed this insect because in warm weather disease destroyed entire cultures. The six liberations made totalled some fifteen thousand moths, larvae and eggs, but the species was not established. This was attributed to predators, particularly scorpion flies (*Harpobittacus australis* Klug. (Bittacidae)) which rapidly destroyed the colonies.

Attempts to culture *Hylemyia seneciella* in the laboratory were unsuccessful as the adults emerging from imported puparia did not oviposit. In consequence, this species was not released in the field.

It was considered that, if the initial liberations of *Callimorpha jacobaeae* were sufficiently large, the population in the field might increase despite the losses caused by predators, and the species might be established. For this reason, C.S.I.R.O. renewed work on this problem, and imported *Callimorpha jacobaeae* from Italy in 1955, and from England in 1955 and 1957. Liberations in the

field were made in 1956 and 1957. This work is continuing, and it is intended to import *Hylemyia seneciella* from New Zealand in the near future.

Ragwort can now be killed on farmland by weedicides, though only at rather heavy expense. However, land treated with weedicides may become reinfested by seed in the soil or seed from ragwort in adjacent uncultivated land, and such reinfestation necessitates repeated applications of weedicide. Biological control remains, therefore, a desirable objective.

Sources
89, 97 (1954–7), 116 (1928–40), 121, 554.

(8) **Nut-grass**—*Cyperus rotundus* L.(Cyperaceae)

Cyperus rotundus is a cosmopolitan perennial which is onsidered to be native to Australia. It occurs in all the mainland States, is widespread and abundant along the coastal districts of eastern and southern Australia, and is a serious pest of cultivated land in Queensland and New South Wales.

Nut-grass has no useful properties itself, but there are other species of the genus in Australia, and two of these, *C. retzii* Nees and *C. victoriensis* Clarke, which occur widely in the interior of the continent, are of value. On heavy clay soils away from the coast, *C. retzii* is considered to be an excellent fodder plant. *C. victoriensis* has much less use for fodder, but is of value in preventing erosion of stream banks and the consequent silting of the channels.

The biological control of nut-grass in Australia has been considered from time to time, but not investigated in any detail. About 1901, a species of *Antonina* (Pseudococcidae), subsequently described as *australis* Green, was found attacking nut-grass in New South Wales. The species was distributed by farmers and others from 1901 onwards for several years. It was also sent from New South Wales to Queensland and Victoria (Mildura) in 1903. In this year it was found in Queensland at the Herbert River, and it was suggested that it might have been introduced into that State from New South Wales even before 1896. It was also introduced into Queensland from New South Wales in 1910 and liberated in the Bundaberg district, whence it was distributed to most of the coastal areas where nut-grass occurred in any quantity. *Antonina australis* was found to be associated with two grasses in Queensland, a native and an introduced species, and dissemination of the coccid was discountenanced by the Department of Agriculture and Stock. This insect has frequently been reported to cause much damage to nut-grass, particularly during dry seasons and where the ground is left undisturbed but the degree of control usually exercised by this insect appears to be slight. It seems probable that *Antonina australis* was widely present in eastern Australia before its artificial distribution was undertaken.

C.S.I.R. introduced the following enemies of nut-grass:

Species	Introduced	
	Origin	Year
Athesapeuta cyperi Marsh.(Curculionidae)	Hawaii	1936, 1938
Bactra truculenta Meyr.(Tortricidae)	Hawaii	1936, 1938, 1940

These introductions were made to determine whether the insects would attack useful fodder species of *Cyperus*. Neither insect was released. It was considered that the risk to the useful species was too great, and that even heavy insect attack was unlikely to have a significant effect on the abundance of the weed as vegetative propagation below ground is very rapid and takes place under adverse conditions.

Sources
71, 89, 116 (1935–41), 209, 287, 469 (1913–5, 1927–8, 1933–4), 496, 521.

(9) **Common heliotrope**—*Heliotropium europaeum* L.(Compositae)

This annual is a serious weed over a large area in New South Wales, Victoria and South Australia. There seems to be no doubt that it is an introduced species, but its presence since the

early days of colonization led some botanists to conclude that it was native to Australia. Common heliotrope is poisonous to sheep, ingestion of the weed causing pathological changes in the liver and predisposing the sheep to chronic copper poisoning.

The possibility of the biological control of common heliotrope was investigated by C.S.I.R.O. From a study of the climatic characteristics of the areas infested in Australia, climatic analogues were determined in the western Mediterranean, where the species is indigenous. These areas (southern France, eastern Spain, coastal Algeria and Tunisia) were surveyed in 1950 for insects associated with *Heliotropium* (F. Wilson, unpublished data).

The insects associated with *Heliotropium* are chiefly polyphagous species. One of these, *Utetheisa pulchella* (L.) (Arctiidae), which is abundant on *Heliotropium europaeum* in the Mediterranean, is widespread and abundant in Australia, and has been reported to cause defoliation of common heliotrope over large areas of South Australia, and to kill out large areas of the weed in New South Wales. A few insects on *Heliotropium* are possibly restricted to the genus. The most promising of these is *Longitarsus albineus* Foud.(Halticidae), the adults of which damage the leaves of *H. europaeum* and were very abundant in the areas explored. However, the larvae of *Longitarsus albineus* have not yet been found in nature, and investigations made on behalf of C.S.I.R.O. by the Commonwealth Institute of Biological Control have cast doubt on whether the adults are restricted to *Heliotropium*, and have raised the possibility that the larvae live on some other host. Although these questions have not been settled, they have discouraged further investigation. No insects have been imported into Australia in connection with this problem.

Sources
65, 82, 97 (1950–2), 130, 385, 403 (1949–50), 554.

(10) **Skeleton weed**—*Chondrilla juncea* L.(Compositae)

Chondrilla juncea is the most important weed of cereal crops in New South Wales. It is also abundant in Victoria and South Australia. This species is a perennial, and native to Europe, North Africa, and western Asia. It is difficult to control by chemicals, and although a useful grazing species, its biological control has sometimes been strongly urged.

C.S.I.R. made some incidental investigations into the complex of insects associated with this weed in southern France. In that area, the more important insects appeared to be three species attacking the capitula, *Dasyneura* n. sp. (Cecidomyiidae), *Ensina sonchi* L.(Trypetidae), and *Tephritis nesii* Wied.(Trypetidae), and a leaf-miner, *Melanagromyza cunctata* Hend.(Agromyzidae). Many other insects have been recorded from *Chondrilla*, two of particular interest being a root borer, *Sphenoptera foveola* Gebl.(Buprestidae), and a stem borer, *Mordellistena micans* Germ.(Mordellidae). The insects attacking *Chondrilla* tend to be polyphagous species, and there is some doubt whether insect enemies of sufficiently narrow host range exist. No insects have so far been introduced into Australia.

Sources
116 (1933–7), 119.

SUMMARY OF RESULTS

Of the weeds dealt with in the preceding section, no insects were imported against Bathurst burr, common heliotrope, mist-flower and skeleton weed, and no insects were liberated against nut-grass as those imported were not considered sufficiently specific. The only insect liberated against ragwort was *Callimorpha jacobaeae*, and this was not established but a fresh attempt to establish this insect is in progress. Introduced insects have been established against the other weeds (prickly pear, St. John's wort, lantana, Noogoora burr, Crofton-weed and gorse) and the results obtained are summarized below.

Prickly pear (pp. 51-56)

In general, the biological control of prickly pear has been extremely effective, especially in Queensland where the problem was most severe. In New South Wales, the only other State with a serious prickly pear problem, the level of control has been less complete. The insects which contributed most to the success obtained against the different species of prickly pear were:

O. inermis and *O. stricta* .. *Cactoblastis cactorum*
O. auriantiaca .. .. .. *Dactylopius* sp. near *confusus*
O. streptacantha .. .. .. *D. opuntiae* and *C. cactorum*
O. tomentosa .. .. *D. opuntiae*
O. vulgaris .. .. *D. ceylonicus*

The following table lists the species of *Opuntia* in order of their importance as weeds (the first two were of outstanding importance), and indicates the degree of biological control obtained in the two States.

Species of *Opuntia*	Degree of biological control in	
	Queensland	New South Wales
inermis	Complete	Generally satisfactory
stricta	Complete	Not present
aurantiaca	Complete	Partial
streptacantha	Partial	Not present
tomentosa	Partial	Controlled by other means: very little present
vulgaris	Complete	Partial
imbricata	Controlled by other means: very little present	Controlled by other means

St. John's wort (pp. 56-59)

Chrysomela quadrigemina and *C. hyperici* have been widely reported to cause severe defoliation and much mortality of the weed. A survey throughout Victoria, the State worst infested, has shown that on cleared land the beetles have given spectacular results in many areas. Farmers generally have followed insect attack by pasture improvement, and this has resulted in many areas being brought back into full production. Where it has been impossible to follow insect destruction of the weed by pasture improvement, as on Crown lands, the weed frequently becomes re-established. Much Crown land is timbered, and the beetles are not effective in timbered areas. No general survey has been reported from New South Wales, but presumably the insects have been less effective there. In South Australia, substantial reduction in the abundance of St. John's wort has occurred in some localities, notably in the Yankalilla district.

Lantana (pp. 59-61)

Earlier reports attributed importance to the damage to lantana caused by *Agromyza lantanae* and *Teleonemia scrupulosa*, but it now appears that these insects are of little importance, if any, in controlling lantana on mainland Australia. The comparatively recent establishment of *Teleonemia scrupulosa* on Norfolk Island, however, has resulted in a markedly adverse effect on the weed, and it is considered that eradication by mechanical means would now be very much easier.

Crofton-weed (p. 61)

Procecidochares utilis is widespread and in certain areas has reduced flowering, seeding, and plant vigour. There is evidence both in Queensland and New South Wales that Crofton-weed has become less aggressive since the establishment of this insect, and there seems to be ground for hope that the introduction may prove effective.

Gorse (pp. 61-62)

Though *Apion ulicis* is well established in Tasmania, no evidence is available concerning reduction in the weed's rate of spread, which was the object of the introduction.

Noogoora burr (pp. 62-64)

Of the many insect enemies of Noogoora burr investigated, only *Euaresta aequalis* was considered to be sufficiently restricted in host range to justify liberation. This insect has become established only in a small area of southern Queensland, and has had no significant effect on the abundance of the weed.

DISCUSSION

EXOTIC AND NATIVE PESTS AS SUBJECTS FOR BIOLOGICAL CONTROL

Many insect pests in Australia are exotic species which are well-known pests of crops in other parts of the world and have reached Australia since it was first colonized. Intermittently, exotic insects continue to gain admittance to Australia, although there are many important agricultural pests from which Australia still remains free. Most biological control research in Australia has been directed towards the control of such accidentally introduced exotic species. However, attempts have also been made to attain biological control of some native pests, and of some cosmopolitan pests (chiefly scale insects) whose origins are obscure. These cosmopolitan species are listed below under a separate heading, though from the viewpoint of biological control investigation, the cosmopolitan scale insects are probably best regarded as exotic species. It should be noted that although 'mosquitoes' are included in the 'native' lists, both native and cosmopolitan species are involved.

It is useful to consider the extent to which biological control has been attempted against exotic, cosmopolitan and native pests, and the degree of success attained against pests of each category. In drawing up the following lists, a number of the attempts at biological control dealt with earlier have been eliminated from consideration; these comprise some of the minor investigations and some which are too recent for conclusions as to success or failure. Apart from these omissions, the Australian and Australian New Guinea pests are separated below into exotic, cosmopolitan and native categories, and where some useful degree of biological control is considered to have been obtained, the name of the pest is preceded by two asterisks (indicating a higher degree of biological control), or one asterisk (indicating a lower degree).

AUSTRALIA

Exotic

*Lucerne flea
Pine aphid
*Cabbage aphid
**Vine scale
Pink wax scale
**Mealy bugs
*Apple leafhopper
*Cabbage white butterfly
Potato moth
Oriental fruit moth
Banana weevil borer
Pear and cherry slug
Buffalo fly
**Woolly aphid
*Oak aphid
Black citrus aphid
White wax scale
**Golden oak scale
**Greenhouse white fly
**Green vegetable bug
*Cabbage moth
Codling moth
Cane weevil borer
Pea weevil
Mediterranean fruit fly
Garden snail

Cosmopolitan

**Black scale
*Red scale
*Soft brown scale
San José scale

Native

Grasshoppers
White grubs
Australian sheep blowfly
Underground grass grubs
Queensland fruit fly
*Mosquitoes

Exotic

None except for recent work on rhinoceros beetle and giant African snail.

Cosmopolitan

Coconut scale

*Sweet potato hawk moth

Native

*Coconut grasshoppers
**Coconut leafminer
*Mosquitoes

Caçao weevil borer
Coconut leaf Hispa

Useful results against Australian pests have been obtained in twelve out of twenty-six in the exotic category, three out of four in the cosmopolitan category, and one out of six in the native category. Combining the exotic and cosmopolitan pests, a relatively high degree of control was obtained with a quarter of them, and lower degree of control with another quarter. However, amongst the exotic pests in which attempts at biological control were ineffective are several (potato moth, pear and cherry slug, garden snail, and possibly others) which might repay further biological control investigation. It should perhaps be reiterated that, with the possible exception of greenhouse white fly, the degree of control obtained is in no instance complete, but is a partial control which has diminished each problem to the extent indicated earlier.

In sharp contrast with the results obtained against exotic and cosmopolitan pests, attempts at the biological control of native species in Australia have been ineffective, except for the introduction of the mosquitofish which in suitable habitats has proved of use against mosquitoes, whether native or cosmopolitan.

In Australian New Guinea, the numbers of problems undertaken and the results obtained have borne a different relation to the exotic, cosmopolitan, and native categories. Successes have been reported against one cosmopolitan pest and three included in the native category. Some degree of control of mosquitoes and the sweet potato hawk moth has been provided by the mosquitofish and the giant toad respectively. Of the other two native pests, coconut grasshoppers have been controlled by a parasite of a related host from Amboina, and the coconut leafminer has been controlled by a Javanese parasite of a related species. It appears that, because of the great diversity and limited distribution of the insect fauna in the numerous islands of this tropical region, the possibility exists of improving the levels of biological control of some native pests by introducing natural enemies of related species from other islands.

If the Hemiptera are separated from the other pests, the preceding lists may be contracted into the following form:

Degree of biological control		No. of pests		
		Higher	Lower	None
		Australia		
Exotic	Hemiptera	6	3	4
	Others	–	3	10
Cosmopolitan	Hemiptera	1	2	1
	Others	–	–	–
Native	Hemiptera	–	–	–
	Others	–	1	5
		Australian New Guinea		
Exotic	Hemiptera	–	–	–
	Others	–	–	–
Cosmopolitan	Hemiptera	–	–	1
	Others	–	1	–
Native	Hemiptera	–	–	–
	Others	1	2	2

Biological control has been markedly more effective against exotic and cosmopolitan Hemiptera than against insects of other groups. Some degree of success has been obtained with twelve of the eighteen Hemiptera listed, and with eight of the twenty-five non-Hemiptera. The greater success with the Hemiptera is emphasized by the fact that of the eight pests against which a higher degree of control is recorded seven are Hemiptera.

So far as the biological control of weeds is concerned, all the more detailed Australian investigations, whether successful or unsuccessful, have been concerned with exotic weeds. Few of the more important weeds in Australia are native species, exceptions being nut-grass, galvanized burr (*Bassia birchii* F. Muell., Chenopodiaceae) and Afghan thistle (*Solanum hystrix* R. Br., Solanaceae). Bracken (*Pteridium aquilinum* (L.) Kuhn, Polypodiaceae), a cosmopolitan species, is also among the more serious weeds. Some investigations were made on the natural enemies of nut-grass, *Bassia* spp. and bracken, but the work did not proceed to the liberation of phytophagous insects.

No work on the biological control of weeds has been carried out in Australian New Guinea.

SOURCES OF BENEFICIAL SPECIES ESTABLISHED

It has been shown earlier that natural enemies of pests have been introduced into Australia and New Guinea from many parts of the world. The area from which material was obtained was often a country where the pest is indigenous, but quite frequently species have been imported from countries where they have been introduced and established against alien pests. There has also been a marked tendency to import beneficial species from countries with which Australia has close ties, such as England, New Zealand, and the United States. The sources of the established natural enemies are of interest for the bearing they have on the suitability of particular geographic areas as sources of beneficial species, and it is worth listing the origins and the main areas of establishment of many of those introduced species which have proved to be of particular value in controlling their hosts or, at least, have become abundant since introduction.

The source given in the following table for each natural enemy is the indigenous area from which the stock was derived. When imported material was obtained from some country other than the indigenous source, this intermediate country is listed in brackets. This table does not provide a complete list of the exotic natural enemies which have been purposely established, nor does it include all those species which have become established accidentally.

	Introduced natural enemy		
Pest	Species	Source	Main areas where established
Sexava spp.	*Leefmansia bicolor*	Amboina	Bismarck Archipelago
Promecotheca papuana	*Pleurotropis parvulus*	Java (Fiji)	Bismarck Archipelago
Dermolepida albohirtum, etc.	*Bufo marinus*	French Guiana (Hawaii) (Queensland)	Queensland New Guinea
Culicidae	*Gambusia affinis*	South-western U.S.A. (Italy)	New Guinea and Australian mainland States
Lantana camara	*Teleonemia scrupulosa*	Mexico (Fiji)	Queensland
Opuntia spp.	*Cactoblastis cactorum*	Argentina	Queensland and New South Wales
	Dactylopius sp. near *confusus*	Argentina	Queensland and New South Wales
	Dactylopius ceylonicus	Argentina (direct and from India and Ceylon	Queensland and New South Wales
	Dactylopius opuntiae	South-western U.S.A. and Mexico	Queensland and New South Wales
Eupatorium adenophorum	*Procecidochares utilis*	Mexico (Hawaii)	Queensland and New South Wales
Aonidiella aurantii	*Aphytis chrysomphali*	Southern China	Australian mainland States
Saissetia oleae	*Aphycus lounsburyi*	South Africa	Australian mainland States
	Scutellista cyanea	South Africa (California)	Australian mainland States except South Australia

Pest	Introduced natural enemy		
	Species	Source	Main areas where established
Nezara viridula	*Microphanurus basalis*	Egypt	Australian mainland States
Plutella maculipennis	*Horogenes cerophaga*	England (New Zealand)	All Australian States
	Thyraeella collaris	England (New Zealand) and Italy	Queensland to Tasmania
Eriosoma lanigerum	*Aphelinus mali*	U.S.A. (New Zealand)	All Australian States
Pieris rapae	*Apanteles glomeratus*	England and/or Canada	All Australian States
	Pteromalus puparum	England (New Zealand)	All Australian States (? except Queensland)
Hypericum perforatum	*Chrysomela quadrigemina*	Southern France	New South Wales and Victoria
	Chrysomela hyperici	England	New South Wales and Victoria
Eulecanium persicae	*Aphycus timberlakei*	? Japan or Philippine Islands	Western Australia and probably elsewhere
Pseudococcids	*Cryptolaemus montrouzieri*	New South Wales	Western Australia
Trialeurodes vaporariorum	*Encarsia formosa*	? (England via New Zealand)	New South Wales, Victoria, South Australia, Tasmania
Typhlocyba froggatti	*Anagrus armatus nigriventris*	? Europe (New Zealand)	Tasmania
Asterolecanium variolosum	*Habrolepis dalmani*	Massachusetts (New Zealand)	Tasmania
Ulex europaeus	*Apion ulicis*	England (New Zealand)	Tasmania

There is an apparent relationship between the source areas and the main areas of establishment, and this may well be the reflection, in part at least, of climatic similarity. It is evident that the species of more tropical origin have been established in the more northern parts of the Australian-New Guinea area, and the species of more temperate origin in the more southerly areas. Notable success has been obtained in establishing in Queensland species originating in the Argentine-Mexico region, and in establishing in Tasmania species previously established in New Zealand. This lends some support to the view that it is desirable to determine climatic analogues of the area infested by a pest when selecting foreign areas for investigation of natural enemies suitable for introduction. Although it has often been stressed that it is not possible to forecast whether an insect from one area can be established in another, logic still demands that adequate attention be given to climatology in biological control investigations.

THE USE OF NATIVE NATURAL ENEMIES

Native natural enemies are of importance in the control of many pests and potential pests in Australia, and attempts have been made to extend the area of distribution of some native species by transferring them from one State to another. Reference was made earlier to the organized exchange of coccinellids which took place, chiefly between Western Australia and eastern Australia, during the period 1895–1902. Other natural enemies were introduced into Western Australia from the eastern States by G. Compere. That Western Australia was ecologically isolated from the rest of the mainland by an extensive arid zone made such introductions seem particularly promising, and some of the insects introduced did prove of value. Among the species recorded as having been established in Western Australia are the following:

(i) *Cryptolaemus montrouzieri* against mealy bugs.
(ii) *Orcus chalybeus* against red scale, etc.
(iii) *Leis conformis* against black citrus aphid, woolly aphid, cabbage aphid, etc.
(iv) *Rhizobius ventralis* against black scale. (However, this species was recorded in Western Australia before being introduced).
(v) *Tomocera californica* against black scale. (This parasite is thought to be native to Australia).

In addition to these, two ichneumon parasites of cabbage aphid (one probably being the cosmopolitan *Diaeretus rapae*), two parasites of cabbage moth (one probably being *Hymenobosmina rapi*),

and various unspecified parasites of black scale and soft brown scale were also introduced into Western Australia from the eastern States. Some of these may be of importance in the control of their hosts in Western Australia. *Opius tryoni*, which was introduced into Western Australia for the control of the Mediterranean fruit fly, apparently did not become established.

The importation of natural enemies into eastern Australia from Western Australia was on a smaller scale than the movement in the opposite direction, and had little or no practical result. So far as is known, none of the Western Australian coccinellids became established in the eastern States, and the transfer of *Biscirus lapidarius*, a predator thought to be of European origin, probably had no important bearing on the lucerne flea problem (p. 27).

The movement of native natural enemies between the other Australian States also had little or no effect. So far as is known, none of the native coccinellids introduced from one State to another in eastern Australia became established. The transfer of large numbers of the cosmopolitan *Nasonia vitripennis* from New South Wales to the other States for the control of the Australian sheep blowfly (p. 40) was quite ineffective. *Diomus pumilio*, which appears to control pine aphid (p. 38) fairly effectively in eastern Australia, was transferred from the Australian Capital Territory to Queensland, but in retrospect it seemed likely that this useful predator had already been present in the area where it was introduced.

There has been little deliberate movement of natural enemies between Australia and New Guinea, chiefly because differences in climate and agriculture cause differences in the pest problems of the two areas. The Australian fishes, *Galaxias attenuatus*, *Carassiops galli*, and *Pseudomugil signifer* have been introduced into New Guinea for the control of mosquitoes (p. 42) but apparently none of them proved useful. It is intended to import *Cryptolaemus montrouzieri* from New South Wales into the Western Highlands of New Guinea for the control of mealy bugs (p. 18) on shade trees. The only natural enemy introduced from New Guinea into Australia is *Ceromasia sphenophori*, a parasite of the cane weevil borer (p. 36), which was imported from Papua into Queensland, but though established, appears to be of no importance.

Within the Territory of New Guinea, there has been some movement of natural enemies from district to district and from one island to another. For the control of the coconut leafminer (p. 23), planters in New Guinea have long fostered the green tree ant (*Oecophylla smaragdina*), and in New Britain *Eurytoma* sp. has been bred and distributed when parasites of the leafminer were slow to appear in the field. Parasites of the coconut scale (p. 17) have been sent to one of the Western Islands, and coccinellid predators of this scale have been forwarded to Pelleluhu Island where predators seemed to be absent. There has been some movement of parasites of coconut grasshoppers (p. 3). An encyrtid and a mymarid were introduced into Manus Island from New Hanover, and this encyrtid was also introduced into New Britain from New Hanover. Unspecified egg-parasites of coconut grasshoppers were transported from Manus and New Hanover to New Ireland and New Britain, and it is intended to transfer parasites of coconut grasshoppers from the mainland of New Guinea to areas where these are pests.

Only one native insect has been used for the biological control of a weed in Australia. This is *Antonina australis* which attacks nut-grass (p. 65). The example is of interest also because of the early date at which it was utilized (1901 or earlier). *Antonina australis* was distributed in New South Wales and Queensland until it was discovered that the coccid attacks other grasses. It sometimes causes severe damage to nut-grass, but in general it appears that the control exercised is slight.

THE USE OF DISEASES

There have been few attempts to use diseases for the control of pests in Australia, and most of these attempts were made many years ago and were unsuccessful. The recent increase in interest in insect diseases and their use for the control of pests has so far had little practical result in Australia.

Most of the early Australian work with diseases was concerned with entomogenous fungi. In 1894, *Botrytis tenella* was imported for the control of white grubs (p. 34), and about that time cultures of this fungus were commercially available and extensively employed, though apparently with little

or no result. In 1914, the green muscardine fungus (*Metarrhizium anisopliae*) was imported for use against *Dermolepida albohirtum* and other white grubs. Experiments with this fungus continued for some years, but apparently led to no useful result. In 1942–3, an attempt was made to employ *Bacillus popilliae* and *B. lentimorbus*, milky disease of Japanese beetle, against *Dermolepida albohirtum* in Queensland, but larvae of this species were not successfully inoculated.

The green muscardine fungus also attacks the cane weevil borer (p. 36), and its use against this insect was contemplated in 1923–4. In 1928, cultures of an entomogenous fungus which attacks a related borer in the Philippine Islands were imported and transmitted to the cane weevil borer, but no results of practical significance were reported.

The chinch bug fungus (*Beauveria globulifera*) was imported into New South Wales in 1901 for use against the Rutherglen bug (p. 30), but there is no record of its release in the field. It was also intended to introduce this fungus in 1903 for use against locusts, but it is not known whether this introduction took place. About 1899–1904, *Mucor racemosus*, which had been sent from South Africa, was distributed widely in Australia for the control of grasshoppers (p. 26), but this fungus had been sent in error instead of the African locust fungus (*Empusa grylli*), and was of course quite ineffective.

In 1957, a granulosis virus of Australian origin was used in the Australian Capital Territory on experimental plots for the control of the cabbage white butterfly (p. 31). The disease was transmitted readily to the caterpillars. The work is continuing.

During investigations on prickly pear (p. 56), some attention was given both overseas and in Australia to plant diseases of the Cactaceae (146). The Prickly-Pear Travelling Commission imported into Australia in 1913–4 an anthracnose disease caused by the fungus *Gloeosporium lunatum*. It is not known if this disease was then liberated, but in 1925–6 it was found in widely separated areas in Australia, and Dodd considered that it had become established some years previously. Another fungus, *Phyllosticta concava*, which produces anthracnose lesions on prickly pears in America, is also established in Australia, being first recorded in 1929. In Australia, bacterial soft rots often accompany infestation by *Cactoblastis cactorum*, but it is not considered that disease played an important part in the control of prickly pear.

A fungus which may prove of importance in the biological control of a weed is *Cercospora eupatorii*, which attacks the leaves of Crofton-weed (p. 61). This disease has caused much defoliation of the weed in Queensland since 1954. It was not deliberately introduced.

The fungus *Colletotrichum xanthii*, which causes anthracnose and seedling blight of Bathurst burr (p. 64) in New South Wales, has been disseminated in that State in recent years. The fungus kills the host and reduces burr production, and in some years has proved a very useful means of control. It is possible that the fungus is more effective in wetter seasons. Its general value in the control of Bathurst burr is uncertain.

THE USE OF NATURAL ENEMIES OTHER THAN INSECTS AND DISEASES

Nearly all the natural enemies introduced into Australia and New Guinea for the control of insect pests have been insects, but in addition to these and to the diseases mentioned in the previous section, several vertebrate and other predators have been introduced.

In 1897, Helms (264) proposed the introduction into Western Australia of five European vertebrate predators (a mole, *Talpa europaea*; a hedgehog, *Erinaceus europaeus*; a shrew, *Sorex vulgaris*; and two toads, *Bufo bufo* and *B. calamita*) to control cutworms, white grubs and other pests. Fortunately, this proposal was not acted upon. However, much later (1935), one of these predators, *Bufo bufo*, was brought to Australia and tested in quarantine as a predator of underground grass grubs (p. 33), but as the toad was not able to attack these insects in their burrows, it was not released in the field.

The only batrachian that has been liberated in Australia is the giant toad, *Bufo marinus*. This toad was imported in 1935 for the control of white grubs (p. 34) and other pests. *Bufo marinus* is widely established in coastal Queensland and is abundant, and it preys on many insects including *Dermolepida albohirtum* and other pests. Though once reported as contributing to the control of the

cane weevil borer (p. 36), it does not appear to have significantly reduced the abundance of any of the pests on which it preys. On the other hand in New Guinea, where the giant toad was introduced in 1936–7, it has been reported to control the sweet potato hawk moth (p. 34) and other unspecified pests.

Another vertebrate predator which has been established in Australia and New Guinea is the mosquitofish, *Gambusia affinis*. Since its introduction in 1926, this species has proved to be a useful predator of mosquitoes (p. 42) in suitable habitats. Another fish, *Tilapia mossambica*, which was introduced into New Guinea as a food fish in 1954, is primarily vegetarian but also eats mosquitoes. It shows promise of being a useful mosquito predator. Several other fishes have been brought into Australia and New Guinea for mosquito control. In addition, the Queensland alga, *Nitella phauloteles*, was introduced into New Guinea to reduce mosquito abundance, but evidently it is entirely ineffective.

The only bird to be imported into Australia for the control of a pest is the cattle egret (*Bubulcus ibis coromandus*), which was released in the Kimberley Division of Western Australia in 1933 for the control of the cattle tick (p. 46). The cattle egret is now widely established (though not perhaps as a result of this introduction), but it has evidently had no effect on cattle tick abundance. It has been proposed to introduce the starling (*Sturnus vulgaris*) into Western Australia for the same purpose.

In New Guinea, predatory snails are being used for the control of the giant African snail (p. 37). *Streptaxis kibweiziensis* imported from Kenya was liberated in 1957, and *Euglandina rosea* was introduced from Florida in 1956.

No predatory mites have been deliberately imported into Australia, but *Biscirus lapidarius*, a predator of the lucerne flea (p. 27), has been distributed in several States, and is of importance in the control of this pest in some areas.

No animals other than insects have been deliberately introduced into Australia for the control of weeds but a mite, *Tetranychus opuntiae*, became established accidentally on prickly pear (p. 54). It showed a marked preference for *Opuntia inermis*, and was one of several species which gave promise of checking prickly pear. It ceased to be of any importance after the establishment of *Cactoblastis cactorum*, and within a few years became rare.

Source
264.

THE SEASONAL LIBERATION OF NATURAL ENEMIES

In the United States, it has been the practice with certain insects, such as *Cryptolaemus montrouzieri*, to organize mass culture and seasonal liberation, in order to compensate for limitations in their capacity to control their hosts, and render them more effective as means of control. This kind of assisted biological control has not been employed in Australia, though there have been some departures from a strict reliance upon the innate capacity of natural enemies to find and destroy their hosts.

In Queensland, there was the intention in 1927 to mass breed *Trichogramma minutum* for the control of codling moth (p. 20), but it was not pursued for more than a year or two, and was not a success.

In New Guinea, the practice of maintaining laboratory stocks of parasites to deal with sudden outbreaks of pests has sometimes been adopted. *Leefmansia bicolor* has proved of value in controlling coconut grasshoppers (p. 3) in the Bismarck Archipelago, and the laboratory rearing and mass liberation of this species in New Britain and New Ireland has brought outbreaks under control on several occasions. Similarly, *Pleurotropis parvulus*, which is a useful parasite of the coconut leafminer (p. 23), has been maintained in the laboratory for release during outbreaks of this pest.

There has also been intermittently, some periodic distribution of *Gambusia affinis* for the control of mosquitoes (p. 42). This has perhaps been somewhat more frequent in New Guinea than in Australia. The stocking or restocking of waters with mosquitofish has taken place largely from waters in which they are abundant, deliberate culture being generally unnecessary.

The effectiveness of *Aphelinus mali* in controlling woolly aphid (p. 5) early in the season is sometimes adversely affected by the numbers of overwintering parasites being reduced by winter and spring spraying and by winter pruning of the aphid-infested wood. The storing of these prunings and their restoration to the orchard in springtime is not uncommonly practiced by orchardists.

In the attempt at the biological control of the Australian sheep blowfly (p. 40), *Nasonia vitripennis* was reared in millions and distributed in New South Wales for some years, though entirely without effect. This parasite was not an imported species, and was doubtless widely distributed when first discovered, and the liberations were perhaps intended to render it more effective rather than merely to establish it in new areas.

In Western Australia, parasites and predators of many scale insects, aphids and other pests were collected and distributed each season for many years. Some of these natural enemies were introduced species and others were native, and their distribution aimed at the wider establishment of the introduced species, and the greater effectiveness of both.

In New South Wales, *Microphanurus basalis*, an egg-parasite of the green vegetable bug (p. 29), was bred in the laboratory and liberated in the field for some years from 1935 onwards. To some extent, this may be regarded as the seasonal liberation of a parasite. There are unfavourable areas for *Microphanurus basalis* in this State, and the persistent liberation aimed partly at preserving the effectiveness of the parasite in areas of marginal favourability.

The species of *Dactylopius* established in Australia on various species of prickly pear (p. 52) have a rather poor capacity to discover uninfested host-plants, and to some extent this inadequacy has been compensated for by artificial distribution. *Dactylopius* sp. near *confusus* is the species most regularly distributed. In New South Wales, its seasonal distribution for the control of *Opuntia aurantiaca* has been organized on rather a large scale for some years.

FACTORS PREJUDICING THE SUCCESS OF INVESTIGATIONS

Australia has for many years been one of the world centres for research on biological control, and both on the theoretical and practical sides the results obtained have been of outstanding interest. To some extent this development has been favoured by certain features of Australian agriculture. That so many of Australia's insect and plant pests are exotic species has given rise to an exceptional need for biological control research: also, large land area and low population density have combined to increase the need for maximum assistance from biotic aids in the control of pests.

The success that has attended biological control investigations might have been greater still were it not for a number of difficulties which have impeded progress. In the first place, the personnel and facilities employed have been very limited in comparison with the number of problems investigated and the great demand by the agricultural community for such research. Particularly in the early period, authorities looked for quick results at minimum cost. In some instances, preliminary study in Australia was cursory, overseas investigation minimized, and field study after the liberation of natural enemies was brief. The work involved occasionally extended little beyond the importation of natural enemies supplied by overseas institutions. Secondly, most of Australia's exotic pests and their natural enemies originate in the northern hemisphere, and their importation involves a change of seasons. The problem of bringing the life-cycle of the imported insects into phase with the season of the southern hemisphere has been a common difficulty.

In much of the earlier work on biological control, maritime transport was used for the importation of natural enemies, and this slow means of travel was very harmful to attempts to establish insects in a country so distant from sources of the required biological material. This obstacle, now largely overcome by air transport, was responsible for much mortality and lack of vigour in imported material, and reduced considerably the number of species and quantity of viable material liberated in Australia.

Taxonomic deficiencies have been evident occasionally in the misidentification of host species both in Australia and during overseas investigations, and also in the failure to identify species before liberation.

The difficulties involved in the introduction, culture and liberation of natural enemies are frequently considerable, presenting a serious obstacle to their establishment. Undoubtedly, many natural enemies which could be established have not been established because of this. To overcome these difficulties, the research worker in this field has need of a larger complement of skilled technical assistance than is customarily necessary for workers in the biological sciences.

Investigations on the biological control of weeds are subject to most of the difficulties encountered in work on the biological control of insects, and have additional problems, the most important of which are connected with the risk of introduced phytophagous insects becoming pests of useful plants. In Australia, the decision as to whether a phytophagous insect can be released with safety is based on a study of its biology, and the results of food tests to which it is subjected. These food tests are often numerous, and sometimes occupy several years. Decisions concerning the liberation of such insects have generally been prudent, and usually species which appear to involve even a slight element of risk have not been released. This caution was based on several considerations. First, Australia was for many years the only continental area engaged in such research, which was then regarded by orthodox entomologists as being biologically unsound. Secondly, limitations of knowledge of the fundamentals of host selection make it difficult to guarantee immunity from risk for any particular introduction. Thirdy, as there is no prior certainty that an insect will control a weed, this advantage cannot be weighed in advance against any evident risks.

These matters have inhibited the liberation of insects for the control of weeds. This is illustrated by listing, for several important weeds, the number of insect species studied overseas, introduced into Australia, liberated and established. Commonwealth Prickly Pear Board entomologists observed one hundred and fifty to one hundred and sixty species on cactus plants overseas, introduced forty-eight, liberated twenty-three and established thirteen. On St. John's wort, thirty-seven monophagous and oligophagous insects are reported: of these, twenty-five were studied in Europe, twelve introduced into Australia, eight liberated and four established. More than eighty insects were reported on Noogoora burr: special attention was given to ten, nine were introduced, and one was liberated and established. It is difficult to see how this selection of the available natural enemies of weeds can at present be made much less severe, but possibly some relaxation in severity is desirable. For example, in retrospect, it seems that it might have been preferable to have liberated the four St. John's wort insects which were imported into Australia but not liberated.

Present practice tends to prohibit the liberation of polyphagous insects which might be useful in controlling weeds and would not, if liberated, prove harmful to useful plants. For example, *Utetheisa pulchella*, which is regarded as one of the principal enemies of common heliotrope (*q.v.*) in the Mediterranean region, would not pass the current standards of host restriction. However, it is already present in Australia, where it causes severe damage to common heliotrope and apparently has not been recorded attacking any useful plant. With such standards of host restriction, it is sometimes found that few or no insects can be liberated against particular weeds. Noogoora burr is an important example in Australia.

In deciding whether an insect shall be liberated for the control of a weed, weight is sometimes given to the judgment made as to its probable effectiveness. While such forecasts are of interest in the light of subsequent events if the liberation is made, it is doubtful if such prejudgments are often sufficiently well founded to be acted upon. It is the rule in biological control work that liberation alone provides satisfactory evidence of capacity or incapacity to control. As only a small proportion of liberated natural enemies prove effective, chance favours the adverse judgment, which is not tested in practice if it prevents the liberation being made. Reticence in acting on such adverse judgments is advisable when one considers that no particular importance was attached to the liberation of *Cactoblastis cactorum* against prickly pear and no particular hopes held of its subsequent usefulness.

Native natural enemies may sometimes present an obstacle to the establishment or effectiveness of phytophagous insects. Predators such as ants and spiders are said to have hampered or prevented the establishment of some insects against St. John's wort, and scorpion flies appear to have been one of the main factors in preventing the establishment of *Callimorpha jacobaeae* against ragwort. There is

also a possibility that parasitism of *Procecidochares utilis* may reduce the capacity of this insect to control Crofton-weed.

THE ADVERSE EFFECTS OF INSECTICIDES ON BIOLOGICAL CONTROL IN AUSTRALIA

Nicholson (429) has discussed the general problem of the indirect effects of spray practice on pest populations. Many other papers provide evidence from the field of the effects of insecticidal practices on the biological control of some pests in Australia. Much of this information relates to the increased abundance of other pests on apple trees when DDT is used to control codling moth.

In New South Wales, heavy infestations of Bryobia mite (*Bryobia praetiosa* Koch, Tetranychidae) and red spider (*Tetranychus telarius* (L.)), developed on apple trees treated with DDT. The importance of *Stethorus* sp. (Coccinellidae) in controlling red spider was strongly indicated when the predator was killed by the sprays used, and red spider persisted much later than usual in the season (402).

The use of DDT on pome fruits increased rather than checked infestation by *Tetranychus telarius* in the Murrumbidgee Irrigation Area, where red spider reached plague numbers on DDT-sprayed trees. The woolly aphid (*Eriosoma lanigerum*) population also built up noticeably, apparently because DDT caused heavy mortality of *Aphelinus mali* (536).

It was found in New South Wales that DDT retarded the development of field populations of *Aphelinus mali* so that woolly aphid infestations were heavy for a longer period. It was recommended that large numbers of twigs bearing parasitized aphids be collected in the orchard in the autumn and placed on infested trees in the spring, and that some trees in each orchard be left unsprayed (537).

In South Australia, the use of DDT against codling moth invariably caused a build-up of *Bryobia praetiosa* in warm districts, and less seriously in cool districts. On irrigated William pears, increase in mite damage outweighed reduction in codling moth damage. This and the complete failure of DDT to control light-brown apple moth (*Tortrix postvittana* (Walk.), Tortricidae) offset its value in codling moth control (337–9).

In Queensland, *Tetranychus telarius* is rarely prevalent on apple trees until early summer, but once DDT is applied its numbers increase rapidly. This mite causes most of the injury each summer in orchards where DDT is used to control codling moth, but *Bryobia praetiosa* and *Eriosoma lanigerum* are also increased. Methods have been devised for the control of the populations of these three species which arise when DDT is used to control codling moth in apples, but these are additions to an already extensive spraying programme, and the costs of spraying necessary to control pests have risen sharply (360–4).

In Victoria, populations of *Bryobia praetiosa* increased phenomenally on apple trees sprayed with DDT against codling moth, and *Tetranychus telarius* also increased. There seemed to be no doubt that this was the result of predators being killed whilst the mites remained unaffected. A similar situation seemed to exist with *Aphelinus mali* and *Eriosoma lanigerum* (269).

In Tasmania, some indication of increase in *Bryobia praetiosa* and *Paratetranychus pilosus* (C. and F.) Tetranychidae) was observed on apple trees sprayed with DDT (379), and the control of *Eriosoma lanigerum* by *Aphelinus mali* is also reported to be adversely affected (*Scymnus vagans* Blackb. is known to prey on the eggs of *Bryobia praetiosa* in this State.) The replacement of some or all of the sulphurs in the spray schedule against black spot of apple by either TMTD (tetra-methyl-thiuram-disulphide)—common name, thiram—or SR 406 (N (trichloromethylthio-) tetrahydrophthalamide) —common name, captan—resulted in increases in *Paratetranychus pilosus*, and possibly in *Bryobia praetiosa* (382). There is some reason to think that the use of DDT on apple trees in this State has affected the control of *Typhlocyba froggatti* by *Anagrus armatus nigriventris* for, although *T. froggatti* is very susceptible to DDT, its populations have increased markedly with the use of DDT for the control of codling moth (381).

In Western Australia, the use of DDT and benzene hexachloride on apple trees to control *T. froggatti* led to heavy infestation by *Bryobia praetiosa* (542). It has also been suggested (C. F. H. Jenkins, personal communication) that the use of DDT for the control of codling moth at Bridgetown, Western Australia, may have contributed to a recent prevalence of San José scale.

In Tasmania, it is considered that there is little prospect of biological control being successful in market gardens against *Plutella maculipennis*, *Pieris rapae*, and *Brevicoryne brassicae* because of the widespread use of DDT and benzene hexachloride (384). This is particularly likely to apply to *Brevicoryne brassicae* which is resistant to DDT.

In the Australian Capital Territory, *Brevicoryne brassicae*, usually a serious pest, is well controlled by its natural enemies if insecticides are not used, or if lead arsenate is sparingly used, for the control of *Pieris rapae* and *Plutella maculipennis* (F. Wilson, unpublished data).

The effectiveness of the parasites and predators of *Aonidiella aurantii* and *A. citrina* on fruit trees in New South Wales is adversely affected by heavy dust deposits, or by sprays such as strong Bordeaux mixture: in addition, residual type sprays such as DDT kill off natural enemies and induce a rapid increase in infestation (267). It has recently been reported from Victoria that a very low level of red scale (p. 14) infestation occurred on citrus in one orchard which had not received regular scale control treatments for about eleven years (58); apparently, lacewings and other natural enemies were providing satisfactory control. In coastal South Australia (Adelaide), unsprayed citrus may remain very nearly free from red scale for years (D. C. Swan, personal communication).

Soft brown scale (p. 12) is generally controlled by natural enemies in Australia, but serious infestations occur on citrus in the Murray Valley, especially when insecticides are used for other purposes. The use of DDT in South Australian citrus groves has produced massive infestations by this scale.

The vine scale (p. 15) in New South Wales (268) is usually well controlled by parasites and predators, but spraying with DDT upsets the natural balance and sometimes gives rise to rapid and spectacular increase of the scale.

It is reported (210) that the hydrogen cyanide fumigation of fruit trees does not reduce the effectiveness of natural enemies of scale pests, because the scale insects are killed whilst the parasites and predators survive.

Little attention has so far been given in Australia to field study of the adverse effect of insecticidal schedules upon the capacity of natural enemies to control their hosts. It is likely that this adverse effect is often considerable, and this important question requires extensive investigation.

Sources

58, 170, 210, 267, 268, 269, 337, 338, 339, 360, 361, 362, 363, 364, 379, 381, 382, 383, 384, 387, 402 (1945–6, 1951–3), 429, 458, 459, 469 (1947–8), 501 (1947–8), 536, 537, 542 (1945–6, 1947–9).

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Antonina australis, **1, 65, 73.**
Antrocephalus pomonellae, **21.**
Anystis baccarum, **13.**
Aonidiella aurantii, **7, 8, 12-14, 49, 69, 71, 72, 79.**
Aonidiella citrina, **13, 79.**
Apanteles glomeratus, **30, 31, 72.**
Apanteles plutellae, **32.**
Apanteles rubecula, **30.**
Apanteles scutellaris, **33.**
Aphelinus diaspidis, **13.**
Aphelinus flavus, **38, 39, 48.**
Aphelinus fuscipennis, **11, 13, 17.**
Aphelinus mali, **4, 5, 6, 48, 72, 76, 78.**
Aphelinus niger, **4.**
Aphelinus sp., **11.**
Aphis chloris, **57.**
Aphobetoideus comperei, **6, 10.**
Aphycus alberti, **12.**
Aphycus flavus, **11.**
Aphycus (*Metaphycus*) *helvolus*, **10, 12.**
Aphycus (*Metaphycus*) *lounsburyi*, **9, 10, 12, 71.**
Aphycus sp., **19.**
Aphycus timberlakei, **14, 15, 48, 72.**
Aphycus verdini, **11.**
Aphytis 'A', **13.**
Aphytis chrysomphali, **12, 13, 17, 49, 71.**
Aphytis citrinus, **13.**
Aphytis lingnanensis, **13.**
Apion ulicis, **61, 67, 72.**
Apple leaf-hopper (see *Typhlocyba froggatti*).
aquilinum, Pteridium.
Araucaria mealy bug (see *Eriococcus araucariae*).
araucariae, Eriococcus.
Argemone mexicana, **51.**
argentatus, Dihammus.
? argentinensis, Tersilochus (*Porizon*).
Aristolochia sp., **9.**
armata, Moneilema.
armatus, nigriventris, Anagrus.
Army worms, **35.**
Asaphes vulgaris, **39.**
Ascogaster carpocapsae, **21.**
Ascogaster quadridentata, **21.**
aspersa, Helix.
Asphondylia opuntiae, **53, 54.**
Aspidiotiphagus australiensis, **13, 17.**
Aspidiotus, **7, 8, 17.**
Aspidiotus destructor, **17, 49, 70.**
Asterolecanium variolosum, **39, 48, 69, 72.**
Ataxia hubbardi, **62, 63.**
Athesapeuta cyperi, **65.**
atrifacies, Leucopis.
atrithorax, Physcus.
attenuatus, Galaxias.
augur, Calliphora.
aurantiaca, Opuntia.
aurantii, Aonidiella ; Toxoptera.
auratus, Carassius.
aureicollis, Campsomeris.
aurilanatus, Nipaecoccus ; Pseudococcus.
australasiae, Orcus ; Scymnus.
Australencyrtus girault, **40.**
Australian sheep blowfly (see *Lucilia cuprina*).
australicum, Biscirus ; Trichogramma.
australiensis, Aspidiotiphagus.
australis, Antonina ; Calliphora ; Dibrachys ; Harpobittacus ; Hydrotaea ; Scapanes.
Austroicetes cruciata, **26.**
Azalea white fly (see *Aleyrodes azaleae*).
azaleae, Aleyrodes.

baccarum, Anystis.
Bacillus euloomarahae, **35.**
Bacillus lentimorbus, **35, 74.**
Bacillus lentimorbus var. *australis*, **35.**
Bacillus popilliae, **35, 74.**
Bacterial soft rot, **74.**
Bactra truculenta, **65.**
Baeoanusia minor, **9, 10.**
Banana scab moth (see *Nacoleia octasema*).
Banana weevil borer (see *Cosmopolites sordidus*).
Baris callida, **62, 63.**
Baris interstitialis, **62, 63.**
basalis, Microphanurus.
Bassia birchii, **71.**
Bassia spp., **51.**
Bassus (see *Agathis*).
Bassus sp., **21.**
Bathurst burr (see *Xanthium spinosum*).
Batrachedra sp., **13, 17.**
Batrachedra sparsella, **17.**
Beauveria (*Sporotrichum*) *globulifera*, **26, 30, 74.**
beckii, Lepidosaphes.
bellus, Opius.
beneficus, Anicetus.
bicolor, Leefmansia.
bicristatus, Cheiloneuroides.
bifasciata, Comperiella.
bilunulatus, Orcus.
bipunctata, Adalia.
birchii, Bassia.
Biscirus australicum, **27.**
Biscirus lapidarius, **27, 49, 73, 75.**
Biscirus symmetricus, **27.**
bivulnerus, Chilocorus.
Black citrus aphid (see *Toxoptera aurantii*).
Black orange aphid (see *Toxoptera aurantii*).
Black scale (see *Saissetia oleae*).
Blaesoxipha (*Masicera*) *pachytyli*, **26.**
boerneri, Chermes.
boisduvali, Anoplognathus.
Boophilus microplus, **46, 47.**
Bothriophryne ceroplastae, **15, 16.**
Botrytis tenella, **34, 73.**
boucheanus, Dibrachys.
Brachymeria dipterophaga, **40.**
Brachymeria rubriventris, **40.**
Bracken (see *Pteridium aquilinum*).
Bracon (*Microbracon*) *gelechiae*, **33.**
brassicae, Brevicoryne.
braziliensis, Pseudeucoila (*Hexamerocera*) ; *Huamerocera.*
brevicornis, Nasonia.
Brevicoryne brassicae, **27, 28, 48, 50, 69, 72, 79.**
brevisetosus, Dectes.
bromeliae, Diaspis.
Brontispa froggatti, **23.**
Brontispa longissima, **23, 24, 49, 70.**
brontispae, Tetrastichus (*Tetrastichodes*).
Bruchus pisorum, **37, 50, 69.**
brunsvicensis, Chrysomela.
Bryobia praetiosa, **78.**
Bubulcus ibis coromandus, **46, 75.**
Buffalo fly (see *Siphona exigua*).
Bufo bufo, **32, 33, 74.**
Bufo calamita, **74.**
Bufo marinus, **33, 34, 35, 36, 49, 71, 74.**
bullans, Camaromyia.

Cabbage aphid (see *Brevicoryne brassicae*).
Cabbage centre-grub (see *Hellula undalis*).
Cabbage moth (see *Plutella maculipennis*).
Cabbage white butterfly (see *Pieris rapae*).
Cacao longicorn (see *Glenea aluensis*).
Cacao weevil borer (see *Pantorhytes plutus*).
cacti, Dactylopius.
Cactoblastis cactorum, **52, 53, 54, 55, 56, 67, 71, 75, 77.**
Cactoblastis doddi, **52, 54.**
Cactophagus spinolae, **53, 54.**
cactorum, Cactoblastis.
calamita, Bufo.
californica, Tomocèra.
Caliroa cerasi, **24, 50, 69, 70.**
Caliroa limacina, **24.**
callida, Baris.
Calliephialtes messor, **20.**
Callimorpha (*Tyria*) *jacobaeae*, **64, 66, 77.**
Callineda testudinaria, **6, 18.**
Calliphora augur, **39.**
Calliphora australis, **39.**
Calliphora nociva, **39.**
Calliphora stygia, **39.**
calliphorae, Chalcis.
camara, Lantana.
Camaromyia bullans, **63, 64.**
Campoplex (*Omorgus*) *phthorimaeae*, **33.**
Campsomeris aureicollis, **35.**
Campsomeris marginella modesta, **35.**
Campsomeris tasmaniensis, **35.**
Cane weevil borer (see *Rhabdoscelus obscurus*).
caninae, Mesoleius.
canyona, Chelinidea.
capensis, Dactylopius.
capitata, Ceratitis.
Carassiops galii, **42, 43, 45, 73.**
Carassius auratus, **42, 45.**
cardinalis, Rodolia.
carpocapsae, Ascogaster.
Casca chinensis, **13.**
Casca n. sp., **13.**
Casca wannsiensis, **13.**
Catabena esula, **60, 61.**
Catoblemma dubia, **10, 12, 13, 15, 17, 18.**
Catoblemma sp., **11, 12.**
Cattle tick (see *Boophilus microplus*).
caudata, Lepidiota.
caudatus, Ephialtes.
cavus, Dibrachys.
celerio, Hippotion.
Centaurea spp., **51.**
Cerapterocerus inutilis, **15.**
cerasi, Caliroa.
Ceratitis capitata, **24–26, 50, 69.**
Cercospora eupatorii, **61, 74.**
cerealella, Sitotroga.
cereus, Opius.
ceriferus, Ceroplastes.
Ceromasia sphenophori, **36, 49, 73.**
cerophaga, Horogenes.
ceroplastae, Aneristus ; Bothriophryne.
Ceroplastes ceriferus, **15, 16.**
Ceroplastes destructor, **15, 16, 50, 69.**
Ceroplastes floridensis, **16.**
Ceroplastes luteolus, **16.**
Ceroplastes rubens, **16, 17, 19, 50, 69.**
Ceroplastes spp., **16.**
ceroplastis, Tomocera.
ceylonicus, Dactylopius.
? *Chaetoleucopis dactylopivora*, **18.**
Chalcis calliphorae, **40.**
chalybeus, Orcus.
Chanda (*Ambassis*) spp., **42.**
Cheiloneuroides bicristatus, **10.**
Chelinidea canyona, **53, 54.**

Chelinidea tabulata, **53, 54, 55.**
Chelinidea vittiger, **53, 54.**
Chelonus phthorimaeae, **33.**
Chermes boerneri, **37, 38, 50, 69.**
Chermes pini, **38.**
Chermes strobi, **38.**
Chilocorus bivulnerus, **7.**
Chilocorus circumdatus, **7, 17.**
Chilocorus stigma, **7, 17.**
Chilomenes quadriplagiata, **4, 6, 7, 9, 13, 14, 27.**
Chilomenes quadripustulatus, **7.**
Chinch bug fungus (see *Beauveria globulifera*).
chinense, *Xanthium.*
chinensis, *Casca ; Pachylister* (*Platylister*).
chloris, *Aphis.*
Chondrilla juncea, **51, 66.**
Chortoicetes terminifera, **26.**
Chromocryptus antipodialis, **21.**
Chrysanthemum aphis, **4.**
Chrysolina (see *Chrysomela varians*).
Chrysomela brunsvicensis, **57, 58.**
Chrysomela didymata, **57.**
Chrysomela gemellata, **57.**
Chrysomela geminata, **57.**
Chrysomela hyperici, **57, 58, 67, 72.**
Chrysomela quadrigemina, **57, 58, 67, 72.**
Chrysomela (*Chrysolina*) *varians*, **57, 58.**
chrysomphali, *Aphytis.*
Chrysomphalus ficus, **13, 19.**
Chrysomphalus sp., **13.**
Chrysomyia micropogon, **39.**
Chrysomyia rufifacies, **39.**
Chrysopa ramburi, **18.**
Chrysopa signata, **17.**
Chrysopa sp., **6, 19.**
chrysopila, *Hermetia.*
Chrysopilus ferruginosus, **23.**
Circular black scale (see *Chrysomphalus ficus*).
circumdatus, *Chilocorus.*
cirsii, *Tryoxis.*
citri, *Dactylopius ; Planococcus ; Unaspis.*
? *citri*, *Planococcus.*
citrifolii, *Siphonophora.*
citrina, *Aonidiella.*
citrinus, *Aphytis.*
Citrus aphids, **6.**
Citrus mealy bug (see *Planococcus citri*).
clariscutellum fasciafacies, *Coccophagus.*
clathrata, *Gerstaeckeria.*
Cleobora (*Halyzia*) *mellyi*, **8.**
Cleodiplosis koebelei, **19.**
Coccidoxenus ugandensis, **15.**
Coccinella repanda, **4, 6, 7, 17.**
Coccinella repanda ab. *transversalis*, **4, 6, 7, 27.**
Coccinella septempunctata, **8, 28.**
Coccinella transversoguttata ab. *californica*, **8.**
cocciphaga, *Eublemma ; Thalpochares.*
Coccophagus clariscutellum fasciafacies, **17.**
Coccophagus gurneyi, **18, 19.**
Coccophagus iris, **13.**
Coccophagus isipingoensis, **15.**
Coccophagus lecanii, **11.**
Coccophagus lunulatus, **10.**
Coccophagus lycimnia, **11, 14, 15.**
Coccophagus orientalis, **10, 11.**
Coccophagus scutellaris, **10, 11, 12.**
Coccophagus sp., **16.**
coccus, *Dactylopius.*
Coccus elongatus, **16.**
Coccus hesperidum, **10, 11, 12, 14, 48, 69, 79.**
Coccus longulus, **16.**
Coccus spp., **16.**
Coconut grasshoppers (see *Sexava nubila* and *S. novae-guineae*).
Coconut leaf Hispa (see *Brontispa longissima*).
Coconut leafminer (see *Promecotheca papuana*).
Coconut scale (see *Aspidiotus destructor*).
Codling moth (see *Cydia pomonella*).
Coelophora veranioides, **6.**
Coenopaeus palmeri, **53, 54.**
coenosus, *Hister.*
coffeae, *Saissetia.*
collaris, *Thyraeella.*
Colletotrichum xanthii, **64, 74.**
Common heliotrope (see *Heliotropium europaeum*).
Common prickly pear (see *Opuntia inermis*).
comperei, *Aphobetoideus ; Myiocnema.*
Comperiella bifasciata, **14.**
comstocki near, *Pseudococcus.*
concava, *Phyllosticta.*
concinnus, *Wesmaelius.*
conformis ab. *occidentalis*, *Leis.*
conformis, *Leis.*
confusus capensis, *Dactylopius.*
confusus, *Dactylopius.*
confusus sp. near, *Dactylopius.*
consobrina, *Lepidiota.*
convergens ab. *ambigua*, *Hippodamia.*
convergens, *Hippodamia.*
Copestylum marginatum, **53.**
Copidosoma koehleri, **33, 49.**
coriacea, *Sexava.*
Corrhenes paulla, **64.**
corrugans, *Moneilema.*
Cosmopolites sordidus, **22, 23, 49, 69.**
Cottony cushion scale (see *Icerya purchasi*).
crassa, *Moneilema.*
Craterocephalus fluviatilis, **42, 45.**
crawfordi, *Ophelosia.*
Cristatithorax sp., **11, 15.**
Crocidosema (see *Epinotia lantana*).
Crofton-weed (see *Eupatorium adenophorum*).
cruciata, *Austroicetes.*
Cryptochaetum iceryae, **1.**
Cryptolaemus affinis, **18.**
Cryptolaemus montrouzieri, **1, 6, 12, 15, 17, 18, 19, 37, 48, 56, 72, 73, 75.**
Culex fatigans, **45.**
cunctata, *Melanagromyza.*
cuprina, *Lucilia.*
Cutworms, **34.**
cyanea, *Scutellista.*
cyclades, *Laniifera.*
Cydia molesta, **21, 50, 69.**
Cydia pomonella, **20, 21, 31, 50, 69.**
Cylindrocopturus adspersus, **62, 63.**
Cylindropuntia, **52.**
cymbiforme, *Lecanium.*
cyperi, *Athesapeuta.*
Cyperus retzii, **65.**
Cyperus rotundus, **51, 65.**
Cyperus victoriensis, **65.**

Dactylopius, **8.**
Dactylopius adonidum, **18.**
Dactylopius cacti, **52.**
Dactylopius capensis, **52.**
Dactylopius ceylonicus, **51, 52, 53, 54, 56, 67, 71.**
Dactylopius citri, **18.**
Dactylopius coccus, **53, 54.**
Dactylopius confusus, **53, 54, 55.**
Dactylopius confusus capensis, **52.**
Dactylopius destructor, **18.**

Dactylopius greenii, **52, 53, 54.**
Dactylopius indicus, **1, 51.**
Dactylopius longifilis, **18.**
Dactylopius newsteadi, **53, 54, 56.**
Dactylopius opuntiae, **53, 54, 55, 56, 67, 71.**
Dactylopius sp., **55.**
Dactylopius sp. near *confusus*, **53, 54, 55, 67, 71, 76.**
Dactylopius spp., **55, 76.**
Dactylopius tomentosus, **53.**
dactylopivora, ? *Chaetoleucopis.*
Dactylosternum hydrophiloides, **23, 49.**
Dacus dorsalis, **25.**
dallatoreanum, *Stichotrema.*
dalmani, *Habrolepis.*
Dasyneura n. sp., **66.**
debellator, *Alomya.*
debilis, *Rhizobius.*
Dectes brevisetosus, **62, 63.**
Dectes spinosus, **62, 63.**
delicatus, *Macrocentrus.*
densa, *Isaria.*
dentata, *Melitara.*
dentipes, *Hydrotaea.*
Depressaria hypericella, **57.**
Dermolepida albohirtum, **34, 35, 71, 74.**
destructor, *Aspidiotus ; Ceroplastes ; Dactylopius.*
Devil's rope (see *Opuntia imbricata*).
Diaeretus rapae, **28, 72.**
diaspidis, *Aphelinus.*
Diaspis bromeliae, **19.**
Diaspis echinocacti, **52.**
Diastema tigris, **60.**
Dibrachys australis, **21.**
Dibrachys boucheanus, **21.**
Dibrachys cavus, **21.**
didymata, *Chrysomela.*
Dielis formosus, **35.**
Dihammus argentatus, **61.**
Diomus (see *Scymnus*).
Diomus pumilio, **38, 73.**
dipterophaga, *Brachymeria.*
Dirhinus ruficornis, **40.**
Dirhinus sarcophagae, **40.**
Disonycha varicornis, **53.**
diva, *Zygrita.*
Diversinervus elegans, **10, 15, 16.**
diversus, *Agathis.*
doddalis, *Melitara.*
doddi, *Cactoblastis ; Gerstaeckeria.*
Doirania leefmansi, **4.**
domestica, *Musca.*
dorsalis, *Dacus ; Mesoleius.*
Drooping prickly pear (see *Opuntia vulgaris*).
dubia, *Catoblemma ; Rhopalencyrtoidea.*
Dynastes gideon, **22.**
Dynastes (*Xylotrupes*) *gideon* var. *australicus*, **35.**

echinocacti, *Diaspis.*
Echium spp., **51.**
efformata, *Anaitis.*
elegans, *Diversinervus.*
Eleotris, **42.**
Empusa grylli, **26, 74.**
Encarsia formosa, **28, 48, 72.**
Ensina sonchi, **66.**
Ephialtes caudatus, **20.**
Epinotia (*Crocidosema*) *lantana*, **59, 60.**
Epiplagiops (see *Stomatomyia littoralis*).
Erinaceus europaeus, **74.**
Eriococcus araucariae, **37, 48.**
Eriosoma lanigerum, **4, 5, 8, 48, 69, 72, 78.**
Erythmelus schilleri, **11.**
esula, *Catabena.*
esuriens, *Volucella.*
Euaresta aequalis, **62, 63, 67.**
Eublemma cocciphaga, **10.**
Eucomys hortensis, **11.**
Eucomys sp., **11.**
Eucosma polyphaea, **59.**
Euglandina rosea, **37.**
Eulecanium persicae, **11, 14, 15, 48, 69, 72, 75, 79.**
euloomarahae, *Bacillus.*
eupatorii, *Cercospora.*
Eupatorium adenophorum, **51, 61, 67, 71.**
Eupatorium riparium, **51, 61.**
europaea, *Talpa.*
europaeum, *Heliotropium.*
europaeus, *Erinaceus ; Ulex.*
Eurytoma sp., **23, 73.**
Eutreta sparsa, **59, 60.**
evanescens, *Trichogramma.*
exigua, *Siphona.*
Exochomus melanocephalus, **4.**
Exochomus quadripustulatus, **38.**

farinosa, *Isaria.*
fasciata, *Volucella.*
fasciculata, *Oncopera.*
fatigans, *Culex.*
fenestralis, *Horogenes.*
ferruginosus, *Chrysopilus.*
ficus, *Chrysomphalus.*
flandersi, *Tropidophryne.*
flavidissimalis, *Mimorista.*
flavinode, *Praon.*
flavitarsis, *Pseudoleucopis.*
flavithorax, *Myiocnema.*
flavus, *Aphelinus ; Aphycus ; Microterys.*
fletcheri, *Opius.*
floridensis, *Ceroplastes.*
Fluted scale, **7.**
fluviatilis, *Craterocephalus ; Perca.*
formosa, *Encarsia ; Heterandria.*
formosus, *Dielis.*
foveola, *Sphenoptera.*
frenchi, *Lepidiota.*
froggatti, *Brontispa ; Paraspilomicrus ; Typhlocyba.*
fulica hamillei, *Achatina.*
fullawayi, *Opius.*
fulvoventralis, *Stenosterys.*
funestus, *Lagochirus.*
furfuracea, *Pseudholophylla.*
fuscipennis, *Aphelinus.*

gahani, *Pseudococcus.*
Galaxias attenuatus, **42, 45, 73.**
Galaxias spp., **42.**
galii, *Carassiops.*
Galvanized burr (see *Bassia birchii*).
Gambrus stokesi, **21.**
Gambusia affinis, **42–46, 48, 70, 71, 75.**
Garden snail (see *Helix aspersa*).
gelechiae, *Bracon* (*Microbracon*).
gemellata, *Chrysomela.*
geminata, *Chrysomela.*
Gerstaeckeria clathrata, **53.**
Gerstaeckeria doddi, **53, 54.**
Gerstaeckeria hubbardi, **53.**
Gerstaeckeria nobilis, **53.**
Gerstaeckeria porosi, **53.**
Giant African snail (see *Achatina fulica hamillei*).

giardi, Zeuxidiplosis.
gibbosus, Agathis (*Microdus*).
gideon, Dynastes.
gideon var. *australicus, Dynastes* (*Xylotrupes*).
giffardianus, Tetrastichus.
gigas, Moneilema.
giraulti, Australencyrtus.
Glenea aluensis, **23.**
globulifera, Beauveria (*Sporotrichum*).
Gloeosporium lunatum, **52, 74.**
glomeratus, Apanteles.
Glypta rufiscutellaris, **21.**
Gnorimoschema operculella, **33, 34, 49, 69, 70.**
Golden oak scale (see *Asterolecanium variolosum*).
Gonaxis quadrilateralis, **37.**
Goniozus antipodum, **21.**
Gorse (see *Ulex europaeus*).
Grain weevil, **39.**
grandicorne, Xanthogramma.
Grape-vine mealy bug (see *Pseudococcus* sp.).
Grasshoppers, **69.**
Greedy scale, **17.**
Green muscardine fungus (and see *Metarrhizium anisopliae*), **74.**
Green vegetable bug (see *Nezara viridula smaragdula*).
Greenhouse white fly (see *Trialeurodes vaporariorum*).
greenii, Dactylopius.
Greyback cane beetle (see *Dermolepida albohirtum*).
grossepunctatus, Scapanes.
grylli, Empusa.
gurneyi, Coccophagus.

Habrobracon johannseni, **33.**
Habrolepsis dalmani, **39, 48, 72.**
hacquardii, Tefflus.
haemorrhoidalis, Syngamia.
Haltica ignea, **63.**
Halyzia (see *Cleobora mellyi*).
Harpobittacus australis, **64.**
Heliotropium europaeum, **51, 65, 66.**
Helix aspersa, **37, 50, 69, 70.**
Hellula undalis, **34.**
helvolus, Aphycus (*Metaphycus*).
Hemerobius nitidulus, **38.**
Hemerobius stigma, **38.**
Hemilexomyia abrupta, **40.**
Hemispherical scale (see *Saissetia coffeae*).
Hepialus spp., **33.**
Hermetia chrysopila, **53.**
Hermetia hunteri, **53.**
Hermetia illucens, **53.**
hesperidum, Coccus.
Heterandria formosa, **42, 45.**
Heteronychus sanctae-helenae, **35.**
Hexamera alcis, **32.**
Hexamera signata, **32.**
Hexamerocera (see *Pseudeucoila braziliensis*).
Hippodamia convergens, **7.**
Hippodamia convergens ab. *ambigua*, **7.**
Hippotion celerio, **34, 49, 70.**
hirtellus, Rhizobius.
Hister coenosus, **41.**
Horogenes cerophaga, **32, 72.**
Horogenes fenestralis, **32.**
Horogenes (*Inareolata*) *molestae*, **21.**
Horogenes tibialis, **32.**
hortensis, Eucomys.
Huamerocera braziliensis (see *Pseudeucoila* (*Hexamerocera*) *braziliensis*).
hubbardi, Ataxia ; Gerstaeckeria.
humilis, Opius.
hunteri, Hermetia.
hydrophiloides, Dactylosternum.
Hydrotaea australis, **41.**
Hydrotaea dentipes, **41.**
Hylemyia (*Pegohylemyia*) *seneciella*, **64.**
Hymenobosmina rapi, **31, 72.**
hypericana, Lathronympha.
hypericella, Depressaria.
hyperici, Actinotia ; Agrilus ; Chrysomela.
Hypericum perforatum var. *angustifolium*, **51, 56–59, 67, 72.**
hystrix, Solanum.

ibis coromandus, Bubulcus.
Icerya purchasi, **6, 19.**
iceryae, Cryptochaetum.
Ichneumon suspiciosus, **32, 33.**
ignea, Haltica.
illucens, Hermetia.
imbricata, Opuntia.
Inareolata (see *Horogenes molestae*).
incisi, Opius.
indicum, Syntomosphyrum.
indicus, Dactylopius.
inermis, Opuntia.
interstitialis, Baris.
intricata, Oncopera.
intricoides, Oncopera.
Inula spp., **51.**
inutilis, Cerapterocerus.
iris, Coccophagus.
Isaria densa, **34.**
Isaria farinosa, **21.**
isipingoensis, Coccophagus.

jacobaea, Senecio.
jacobaeae, Callimorpha (*Tyria*).
javanus, Plaesius.
johannseni, Habrobracon.
johnsoni, Ooencyrtus.
juncea, Chondrilla.
junctolineella, Olycella.

kibweiziensis, Streptaxis.
koebelei, Cleodiplosis ; Rodolia.
koehleri, Copidosoma.
kraussi, Opius.

laevigata, Moneilema.
laevis, Lepidiota.
lafertei, Orcus.
Lagochirus funestus, **53, 54, 56.**
Lampyris noctiluca, **37.**
lanceolata, Physalis.
lanigerum, Eriosoma.
Laniifera cyclades, **52.**
Lantana camara, **51, 59–61, 67, 71.**
lantana, Epinotia (*Crocidosema*).
lantanae, Agromyza.
lapidarius, Biscirus.
Lathronympha hypericana, **57.**
Lebistes reticulatus, **42, 44, 45.**
lecanii, Coccophagus ; Muscideopsis.
Lecaniobius utilis, **9.**
Lecanium cymbiforme, **14.**
leefmansi, Doirania.
Leefmansia bicolor, **3, 48, 71, 75.**
Leionota spp., **22.**

Leis conformis, **1, 4, 6, 7, 13, 17, 21, 28, 49, 72.**
Leis conformis ab. *occidentalis*, **6.**
Leis sp., **7.**
lentimorbus, *Bacillus.*
lentimorbus var. *australis*, *Bacillus.*
Lepidiota caudata, **35.**
Lepidiota consobrina, **35.**
Lepidiota frenchi, **34, 35.**
Lepidiota laevis, **35.**
Lepidiota rothei, **35.**
Lepidiota trichosterna, **35.**
Lepidosaphes beckii, **13.**
Leptomastidea (*Paraleptomastix*) *abnormis*, **19.**
? *Leptomastix* sp., **18, 19.**
Lestodiplosis pini, **38.**
Leucopis atrifacies, **38.**
Leucopis obscura, **38.**
Light-brown apple moth (see *Tortrix postvittana*).
limacina, *Caliroa.*
Lindorus lophanthae, **13.**
lineola, *Verania.*
lingnanensis, *Aphytis.*
Lipoleucopis praecox, **38.**
Listroderes obliquus, **36, 50.**
Litomastix sp. nov., **22.**
littoralis, *Stomatomyia* (*Epiplagiops*).
lividigaster, *Scymnus* (*Platyomus*).
Lixus tasmanicus, **64.**
Lobesia physophora, **60.**
longicaudatus, *Opius.*
longicaudatus var. *taiensis*, *Opius.*
longifilis, *Dactylopius.*
longispinus, *Pseudococcus.*
longissima, *Brontispa.*
Longitarsus albineus, **66.**
Long-tailed mealy bug (see *Pseudococcus adonidum*).
longulus, *Coccus.*
lophanthae, *Lindorus.*
lounsburyi, *Aphycus* (*Metaphycus*).
Lucerne flea (see *Smynthurus viridis*).
Lucilia cuprina, **39–41, 49, 69.**
lunatum, *Gloeosporium.*
lunulatus, *Coccophagus.*
luteolator, *Perilissus.*
luteolus, *Ceroplastes.*
lycimnia, *Coccophagus.*

Macrocentrus ancylivorus, **21, 33.**
Macrocentrus delicatus, **21.**
Macropodus opercularis, **42, 44, 45.**
Macrosiphum rosae, **28.**
maculipennis, *Plutella.*
mali, *Aphelinus.*
manducator, *Alysia.*
manilae, *Scolia.*
marginatum, *Copestylum.*
marginella modesta, *Campsomeris.*
marinus, *Bufo.*
maritimus, *Pseudococcus.*
Masicera (see *Blaesoxipha pachytyli*).
Mealy bugs (and see *Pseudococcus* spp.), **18, 19, 48, 50, 69.**
Mecas saturnina, **62, 63.**
Mediterranean fruit fly (see *Ceratitis capitata*).
megacantha, *Opuntia.*
Megastigmus sp., **61.**
Melanagromyza cunctata, **66.**
melanocephalus, *Exochomus.*
Melanotaenia nigrans, **42, 45.**
Melitara dentata, **52, 54.**
Melitara doddalis, **52, 54.**
Melitara prodenialis, **52, 54.**
Melitara sp., **52, 54.**
mellyi, *Cleobora* (*Halyzia*).
Mesoleius caninae, **24.**
Mesoleius dorsalis, **24.**
messor, *Calliephialtes.*
Metaphycus (see *Aphycus helvolus* and *A. lounsburyi*).
Metaphycus varia, **17.**
Metapleura potosi, **52, 54.**
Metarrhizium anisopliae, **34, 35, 36, 74.**
mexicana, *Argemone.*
micans, *Mordellistena.*
michiganensis, *Microphthalma.*
Microbracon (see *Bracon gelechiae*).
Microdus (see *Agathis gibbosus*).
Microphanurus basalis, **29, 30, 48, 72, 76.**
Microphthalma michiganensis, **35.**
microplus, *Boophilus.*
micropogon, *Chrysomyia.*
Microterys flavus, **10, 11, 12.**
Microterys sp., **9.**
Midus pygmaeus, **19.**
Mimorista flavidissimalis, **52, 53, 54.**
minor, *Baeoanusia.*
minutum, *Trichogramma.*
misellus, *Prosoplus.*
Mist-flower (see *Eupatorium riparium*).
mitocera, *Oncopera.*
molesta, *Cydia.*
molestae, *Horogenes* (*Inareolata*).
mollipes, *Orcus.*
monacantha, *Opuntia.*
Moneilema armata, **52, 54.**
Moneilema corrugans, **53.**
Moneilema crassa, **52, 54.**
Moneilema gigas, **52, 54.**
Moneilema laevigata, **53, 54.**
Moneilema obtusa, **53.**
Moneilema rugosipennis, **53, 54.**
Moneilema ulkei, **53, 54, 56.**
Moneilema variolare, **53, 54.**
montrouzieri, *Cryptolaemus.*
Mordellistena micans, **66.**
Mormoniella vitripennis, **40.**
Mosquitoes, **41–46, 48, 69, 70, 71.**
mossambica, *Tilapia.*
Mucor racemosus, **26, 74.**
Musca domestica, **39.**
muscidarum, *Spalangia.*
Muscideopsis lecanii, **15.**
Myiocnema comperei, **9, 10, 11, 12, 19.**
Myiocnema flavithorax, **11.**
Myzocallis annulata, **38, 39, 48, 69.**

Nacoleia octasema, **21, 22.**
Narnia pallidicornis, **53, 54.**
Narnia snowi, **53.**
Nasonia brevicornis, **40.**
Nasonia vitripennis, **40, 49, 73, 76.**
nesii, *Tephritis.*
newsteadi, *Dactylopius.*
Nezara viridula smaragdula, **29, 30, 48, 50, 69, 72.**
niger, *Aphelinus.*
nigra, *Saissetia.*
nigrens, *Melanotaenia.*
Nipaecoccus aurilanatus, **18.**
Nitella phauloteles, **46, 75.**
nitidulus, *Hemerobius ; Saprinus.*
nobilis, *Gerstaeckeria.*
nociva, *Calliphora.*
noctiluca, *Lampyris.*

Noogoora burr (and see *Xanthium pungens*), **77.**
notescens, Scymnus.
novae-guineae, Sexava.
nubila, Sexava.
Nupserha antennata, **62, 63.**
Nut-grass (see *Cyperus rotundus*).
Nysius vinitor, **30.**

Oak aphid (see *Myzocallis annulata*).
obliquus, Listroderes.
obscura, Leucopis.
obscurus, Rhabdoscelus.
obtusa, Moneilema.
ocellata, Anatis.
octasema, Nacoleia.
odiosella, Ozamia.
Oecophylla smaragdina, **23, 73.**
Oenopia sp., **7.**
oleae, Saissetia.
olivaceus, Priopis.
Olla abdominalis, **7.**
Olycella junctolineella, **52, 53, 54.**
Omorgus (see *Campoplex phthorimaeae*).
Oncopera fasciculata, **33.**
Oncopera intricata, **32.**
Oncopera intricoides, **32.**
Oncopera mitocera, **33, 35.**
Oncopera rufobrunnea, **32.**
Oncopera spp., **32, 33.**
Ooencyrtus johnsoni, **30.**
Ooencyrtus submetallicus, **30.**
oophilus, Opius.
opercularis, Macropodus.
operculella, Gnorimoschema.
Ophelosia crawfordi, **19.**
Opius ? *africanus,* **25.**
Opius bellus, **24, 25.**
Opius cereus, **24, 25.**
Opius fletcheri, **25.**
Opius fullawayi, **25.**
Opius humilis, **25.**
Opius incisi, **25.**
Opius kraussi, **25.**
Opius longicaudatus, **25.**
Opius longicaudatus var. *taiensis,* **25.**
Opius oophilus, **25.**
Opius persulcatus, **25.**
Opius spp. n., **25.**
Opius tryoni, **24, 25, 73.**
Opius vandenboschi, **25.**
Opuntia aurantiaca, **51, 54, 55, 56, 67, 76.**
Opuntia imbricata, **51, 54, 56, 67.**
Opuntia inermis, **51, 52, 54, 55, 56, 67, 75.**
Opuntia megacantha, **55.**
Opuntia monacantha, **51.**
Opuntia spp., **51–56, 67, 71.**
Opuntia streptacantha, **51, 54, 55, 56, 67.**
Opuntia stricta, **51, 52, 54, 55, 56, 67.**
Opuntia tomentosa, **51, 52, 54, 56, 67.**
Opuntia vulgaris, **1, 51, 52, 54, 56, 67.**
opuntiae, Asphondylia ; Dactylopius ; Tetranychus.
Orange aphis (see *Siphonophora citrifolii*).
Orcus australasiae, **9, 10, 11, 13, 17.**
Orcus bilunulatus, **7.**
Orcus chalybeus, **6, 7, 10, 12, 13, 16, 17, 49, 72.**
Orcus lafertei, **7.**
Orcus mollipes, **7.**
Orcus sp., **7, 9, 14.**
Oriental fruit moth (see *Cydia molesta*).
orientalis, Coccophagus ; Prococcophagus ; Spalangia.
Oryctes rhinoceros, **22, 50, 70.**
oryctophaga, Scolia.
Ozamia odiosella, **52, 53, 54.**

Pachylister (*Platylister*) *chinensis,* **22, 41.**
Pachyneuron sp., **18.**
pachytyli, Blaesoxipha (*Masicera*).
pallidicornis, Narnia.
palmeri, Coenopaeus.
Pantorhytes plutus, **23, 50, 70.**
papuana, Promecotheca.
Paraleptomastix (see *Leptomastidea abnormis*).
Parasierola sp., **21.**
Paraspilomicrus froggatti, **40.**
Paratetranychus pilosus, **78.**
parkeri, Tersilochus (*Porizon*).
parvulus, Pleurotropis.
parvus, Anicetus.
paulla, Corrhenes.
Pea weevil (see *Bruchus pisorum*).
Pear and cherry slug (see *Caliroa cerasi*).
Pegohylemyia (see *Hylemyia seneciella*).
pennipes, Trichopoda.
pennipes var. *pilipes, Trichopoda.*
pennsylvanicum, Xanthium.
Perca fluviatilis, **42, 45.**
perforatum var. *angustifolium, Hypericum.*
Perilissus luteolator, **24.**
Perisemus sp., **21.**
Perisierola angulata, **21.**
perniciosi, Prospaltella.
perniciosus, Quadraspidiotus.
persicae, Eulecanium.
persulcatus, Opius.
phauloteles, Nitella.
phthorimaeae, Campoplex (*Omorgus*) *; Chelonus.*
phygadeuontoides, Polyblastus.
Phyllosticta concava, **74.**
Physalis lanceolata, **51.**
Physcus atrithorax, **17.**
physophora, Lobesia.
Pieris rapae, **30, 31, 48, 50, 69, 72, 79.**
pilosus, Paratetranychus.
Pine aphid (see *Chermes boerneri*).
Pineapple scale (see *Diaspis bromeliae*).
pini, Chermes ; Lestodiplosis.
Pink sugar cane mealy bug (see *Saccharicoccus sacchari*).
Pink wax scale (see *Ceroplastes rubens*).
pisorum, Bruchus.
Plaesius javanus, **22, 23, 36.**
plagiata, Anaitis.
Planococcus citri, **18, 19.**
Planococcus ? *citri,* **19.**
Platylister (see *Pachylister chinensis*).
Platymeris rhadamanthus, **22.**
Platyomus (see *Scymnus lividigaster*).
Platyopuntia, **52.**
Platyptilia taprobanes, **60.**
Pleurotropis parvulus, **23, 48, 71, 75.**
Plutella maculipennis, **31, 32, 48, 50, 69, 72, 79.**
plutellae, Apanteles.
plutus, Pantorhytes.
Polyblastus phygadeuontoides, **24.**
polyphaea, Eucosma.
pomonella, Cydia.
pomonellae, Antrocephalus.
popilliae, Bacillus.
Porina spp., **32.**
Porizon (see *Tersilochus parkeri, T.* ? *argentinensis* and *T.* spp.).
porosi, Gerstaeckeria.

postvittana, Tortrix.
Potato moth (see *Gnorimoschema operculella*).
potosi, Metapleura.
praecox, Lipoleucopis.
praetiosa, Bryobia.
Praon flavinode, **38.**
Praon volucre, **38.**
pretiosus, Tetracnemus.
Prickly pear (see under *Opuntia* spp.).
Priopis olivaceus, **42, 45.**
Procecidochares utilis, **61, 67, 71, 78.**
Prococcophagus orientalis, **10.**
prodenialis, Melitara.
Promecotheca papuana, **23, 48, 70, 71.**
Promecotheca reichei, **23.**
Prosoplus misellus, **63.**
Prospaltella perniciosi, **14.**
pruinosa, Scitala ; Sericesthis.
Pseudeucoila (*Hexamerocera*) *braziliensis*, **24, 25.**
Pseudholophylla furfuracea, **35.**
Pseudococcus acaciae, **18.**
Pseudococcus adonidum, **18.**
Pseudococcus albizziae, **18.**
Pseudococcus aurilanatus, **18.**
Pseudococcus near *comstocki*, **19.**
Pseudococcus gahani, **19.**
Pseudococcus longispinus, **18.**
Pseudococcus maritimus, **18.**
Pseudococcus sp., **18.**
Pseudococcus spp., **19, 72.**
Pseudoleucopis flavitarsis, **19.**
Pseudomugil signifer, **42, 45, 73.**
Psyllobora taedata, **8.**
Psyllobora vigintimaculata, **8.**
Pteridium aquilinum, **51, 71.**
Pteromalus puparum, **30, 31, 72.**
Pteromalus sp., **21.**
pulchella, Utetheisa.
pulchripennis, Scolia.
Pullus (see *Scymnus*).
pumilio, Diomus.
pungens, Xanthium.
puparum, Pteromalus.
purchasi, Icerya.
Purple scale (see *Lepidosaphes beckii*).
pusilla, Volucella.
pusillus, Syrphus.
Pyemotes ventricosus, **23.**
pygmaeus, Midus.
Pyrophorus spp., **22.**

Quadraspidiotus perniciosus, **7, 17, 50, 69.**
quadridentata, Ascogaster.
quadrigemina, Chrysomela.
quadrilateralis, Gonaxis, **37.**
quadriplagiata, Chilomenes.
quadripustulatus, Chilomenes ; Exochomus.
Quaylea whittieri, **9, 10.**
Queensland fruit fly (see *Strumeta tryoni*).

racemosus, Mucor.
Ragwort (see *Senecio jacobaea*).
ramburi, Chrysopa.
rapae, Diaeretus ; Pieris.
rapi, Hymenobosmina.
Red mite, **6, 8.**
Red scale (see *Aonidiella aurantii*).
Red spider (see *Tetranychus telarius*).
reflexa, Salvia.
reichei, Promecotheca.
repanda ab. *transversalis, Coccinella.*
repanda, Coccinella.
reticulatus, Lebistes.
Retropinna semoni, **42, 45.**
retzii, Cyperus.
Rhabdoscelus obscurus, **22, 35, 36, 49, 69.**
rhadamanthus, Platymeris.
Rhinoceros beetle (see *Oryctes rhinoceros*).
rhinoceros, Oryctes.
Rhizobius debilis, **12, 13, 17.**
Rhizobius hirtellus, **17.**
Rhizobius sp., **4, 7, 9.**
Rhizobius ventralis, **1, 6, 7, 9, 10, 12, 16, 17, 72.**
Rhodobaenus tredecimpunctatus, **62.**
Rhopalencyrtoidea dubia, **13.**
riparium, Eupatorium.
Rodolia cardinalis, **1, 6, 7.**
Rodolia koebelei, **7.**
rosae, Macrosiphum.
Rose aphid (see *Macrosiphum rosae*).
rosea, Euglandia.
rothei, Lepidiota.
rotundus, Cyperus.
rubecula, Apanteles.
rubens, Ceroplastes.
rubiginosa, Triscolia.
rubriventris, Brachymeria.
ruficornis, Dirhinus ; Scolia.
rufifacies, Chrysomyia.
rufiscutellaris, Glypta.
rufobrunnea, Oncopera.
rugosipennis, Moneilema.
Rutherglen bug (see *Nysius vinitor*).

sacchari, Saccharicoccus.
Saccharicoccus sacchari, **27, 50.**
saccharicola, Anagyrus.
Saissetia coffeae, **19.**
Saissetia nigra, **16.**
Saissetia oleae, **6, 7, 10, 12, 16, 48, 69, 71, 72.**
Saissetia spp., **16.**
Salvia reflexa, **51.**
Samoan fungus (and see *Metarrhizium anisopliae*), **34.**
San José scale (see *Quadraspidiotus perniciosus*).
sanctae-helenae, Heteronychus.
Saprinus nitidulus, **40.**
Saprinus semistriatus, **40.**
sarcophagae, Dirhinus.
saturnina, Mecas.
Scapanes australis, **22.**
Scapanes grossepunctatus, **22.**
schilleri, Erythmelus.
Scitala pruinosa, **35.**
Scolia manilae, **35.**
Scolia oryctophaga, **22.**
Scolia pulchripennis, **22.**
Scolia ruficornis, **22.**
scrupulosa, Teleonemia.
scutellaris, Apanteles ; Coccophagus.
Scutellista cyanea, **9, 10, 15, 16, 71.**
Scutellista sp., **9, 11.**
Scymnus australasiae, **27.**
Scymnus (*Platyomus*) *lividigaster*, **6, 7.**
Scymnus notescens, **17.**
Scymnus sp. (*Pullus, Diomus*), **9, 17, 19.**
Scymnus suturalis, **38.**
Scymnus vagans, **78.**
semistriatus, Saprinus.
semoni, Retropinna.
seneciella, Hylemyia (*Pegohylemyia*).
Senecio jacobaea, **51, 64, 65.**

septempunctata, Coccinella.
Sericesthis pruinosa, **35.**
Sexava coriacea, **3.**
Sexava novae-guineae, **3, 4, 48, 70.**
Sexava nubila, **3, 4, 48, 70.**
Sexava spp., **71.**
Shot hole disease, **52.**
signata, Chrysopa ; Hexamera.
signifer, Pseudomugil.
Siphona exigua, **41, 49, 69.**
Siphonophora citrifolii, **6.**
Sitotroga cerealella, **39.**
Skeleton weed (see *Chondrilla juncea*).
smaragdina, Oecophylla.
Smynthurus viridis, **27, 49, 69.**
snowi, Narnia.
Soft brown scale (see *Coccus hesperidum*).
Solanum hystrix, **71.**
sonchi, Ensina.
sordidus, Cosmopolites.
Sorex vulgaris, **74.**
South African locust fungus (see *Empusa grylli*).
Spalangia muscidarum, **40.**
Spalangia orientalis, **41.**
Spalangia sundaica, **41, 49.**
sparsa, Eutreta.
sparsella, Batrachedra.
sphenophori, Ceromasia.
Sphenoptera foveola, **66.**
spinolae, Cactophagus.
spinosum, Xanthium.
spinosus, Dectes.
Spiny prickly pear (see *Opuntia stricta*).
Sporotrichum (see *Beauveria globulifera*).
St. John's wort (and see *Hypericum perforatum* var. *angustifolium*), **77.**
Stenosterys fulvoventralis, **40.**
Stethorus sp., **78.**
Stichotrema dallatoreanum, **4.**
stigma, Chilocorus ; Hemerobius.
stokesi, Gambrus.
Stomatomyia (*Epiplagiops*) *littoralis,* **36.**
streptacantha, Opuntia.
Streptaxis kibweiziensis, **37, 75.**
stricta, Opuntia.
strobi, Chermes.
strumarium, Xanthium.
Strumeta tryoni, **24–26, 50, 69.**
Sturnus vulgaris, **47, 75.**
stygia, Calliphora.
submetallicus, Ooencyrtus.
sundaica, Spalangia.
suspiciosus, Ichneumon.
suturalis, Scymnus.
Sweet potato hawk moth (see *Hippotion celerio*).
sydneyensis, Anarhopus.
symmetricus, Biscirus.
Syngamia haemorrhoidalis, **60.**
Syntomosphyrum indicum, **24, 25.**
Syrphus pusillus, **4.**
Syrphus viridiceps, **4.**

tabulata, Chelinidea.
Tachinaephagus zealandicus, **40.**
taedata, Psyllobora.
Talpa europaea, **74.**
tapiacola, Tucumania.
taprobanes, Platyptilia.
tasmanicus, Lixus.
tasmaniensis, Campsomeris.
Tefflus hacquardii, **37.**
telarius, Tetranychus.
Teleonemia scrupulosa, **60, 67, 71.**
tenella, Botrytis.
Tephritis nesii, **66.**
terminifera, Chortoicetes.
Tersilochus (*Porizon*) ? *argentinensis,* **36.**
Tersilochus (*Porizon*) *parkeri,* **36.**
Tersilochus (*Porizon*) spp., **36.**
testudinaria, Callineda.
Tetracnemus pretiosus, **19.**
Tetracnemus sp., **18.**
Tetranychus opuntiae, **53, 54, 55, 75.**
Tetranychus telarius, **78.**
Tetrastichodes (see *Tetrastichus brontispae*).
Tetrastichus (*Tetrastichodes*) *brontispae,* **24, 49.**
Tetrastichus giffardianus, **24, 25.**
Tetrastichus sp., **9.**
Tetrasticlius sp., **9.**
tetricus, Anodontonyx.
Thalpochares cocciphaga, **10.**
Thalpochares sp., **9.**
Thalpochares spp., **8.**
Thecla agra, **59, 60.**
thoracicus, Triaspis.
Thyraeella collaris, **32, 72.**
Thysanus sp., **19.**
tibialis, Horogenes.
Tiger pear (see *Opuntia aurantiaca*).
tigris, Diastema.
Tilapia mossambica, **42, 45, 75.**
timberlakei, Aphycus.
tomentosa, Opuntia.
tomentosus, Dactylopius.
Tomocera californica, **9, 10, 13, 16, 72.**
Tomocera ceroplastis, **16.**
Tortrix postvittana, **78.**
Toxoptera aurantii, **6, 8, 69, 72.**
transversoguttata ab. *californica, Coccinella.*
tredecimpunctatus, Rhodobaenus.
Trialeurodes vaporariorum, **28, 29, 48, 69, 70, 72.**
Triaspis thoracicus, **37.**
Trichogramma australicum, **21.**
Trichogramma evanescens, **20.**
Trichogramma minutum, **20, 31, 75.**
Trichopoda pennipes, **29.**
Trichopoda pennipes var. *pilipes,* **30.**
trichosterna, Lepidiota.
Triscolia rubiginosa, **35.**
Tropidophryne flandersi, **19.**
truculenta, Bactra.
tryoni, Opius ; Strumeta.
Tryoxis aceris, **38.**
Tryoxis cirsii, **38, 48.**
Tucumania tapiacola, **52, 53, 54, 55.**
Typhlocyba froggatti, **19, 20, 48, 69, 72.**
Tyria (see *Callimorpha jacobaeae*).

ugandensis, Coccidoxenus.
Ulex europaeus, **51, 61, 62, 68, 72.**
ulicis, Apion.
ulkei, Moneilema.
Unaspis citri, **13, 19.**
undalis, Hellula.
Underground grass grubs (and see *Oncopera* spp.), **50, 69.**
Utetheisa pulchella, **66, 77.**
utilis, Lecaniobius ; Procecidochares.

vagans, Scymnus.
vandenboschi, Opius.

vaporariorum, Trialeurodes.
varia, Metaphycus.
varians, Chrysomela (*Chrysolina*).
varicornis, Disonycha.
variolare, Moneilema.
variolosum, Asterolecanium.
Vegetable weevil (see *Listroderes obliquus*).
Velvety tree pear (see *Opuntia tomentosa*).
ventralis, Rhizobius.
ventricosus, Pyemotes.
Verania lineola, **7.**
veranioides, Coelophora.
verdini, Aphycus.
victoriensis, Cyperus.
vigintimaculata, Psyllobora.
Vine scale (see *Eulecanium persicae*).
vinitor, Nysius.
viridiceps, Syrphus.
viridis, Smynthurus.
viridula smaragdula, Nezara.
vitripennis, Mormoniella ; Nasonia.
vittiger, Chelinidea.
Volucella esuriens, **53.**
Volucella fasciata, **53.**
Volucella pusilla, **53.**
volucre, Praon.
vulgaris, Asaphes ; Opuntia ; Sorex ; Sturnus.
wannsiensis, Casca.
Wesmaelius concinnus, **38.**
White grubs, **34–36, 49, 69.**
White louse scale (see *Unaspis citri*).
White spine prickly pear (see *Opuntia streptacantha*).
White wax scale (see *Ceroplastes destructor*).
whittieri, Quaylea.
Woolly aphid (see *Eriosoma lanigerum*).

xanthii, Colletotrichum.
Xanthium chinense, **62.**
Xanthium pennsylvanicum, **62.**
Xanthium pungens, **51, 62–64, 68.**
Xanthium spinosum, **51, 62–64.**
Xanthium spp., **51.**
Xanthium strumarium, **62.**
Xanthogramma grandicorne, **6.**
Xylotrupes (see *Dynastes gideon* var. *australicus*).

Yellow scale (see *Aonidiella citrina*).

zealandicus, Tachinaephagus.
Zeuxidiplosis giardi, **57, 59.**
Zygrita diva, **64.**